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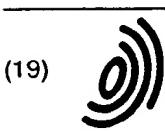
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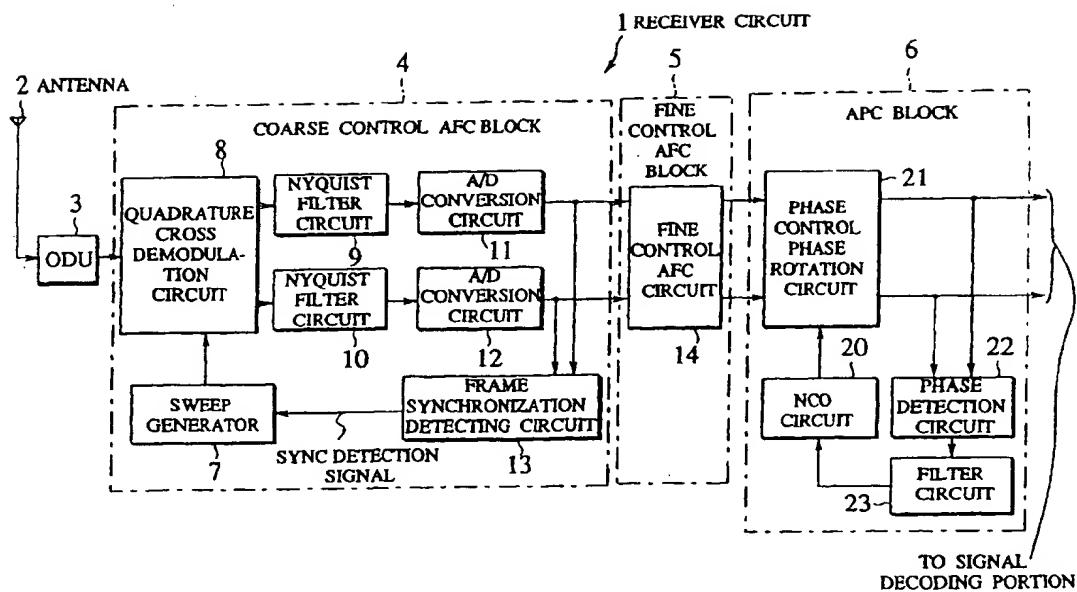
(54) AFC CIRCUIT, CARRIER REPRODUCING CIRCUIT, AND RECEIVER

(57) Stabilized carrier recovery is achieved even at the time of a low C/N ratio by measuring the phase of a signal and controlling VCO or NCO (Numerical Controlled Oscillator) using only a period having few constellation points. At this time, false lock phenomenon is avoided as follows. That is, relatively short SYNC modulated by an already-known pattern is entered into a modulation wave, VCO or NCO oscillation frequency is swept in a wide range and sweep is stopped at a frequency in which the SYNC can be received, thereby carrying out coarse control AFC. Further, a period having long to some extent, having few constellation points is provided in the modulation wave and then, a difference between the frequency of a received modulated signal and a local oscillation signal of VCO or NCO is obtained in this period. This frequency difference is analyzed according to the phase differential function method, self-correlation function method or count method, and the VCO or NCO is controlled based on

this result of analysis.

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FIG.2



Description	Background Art
Technical Field	
<p>[0001] The present invention relates to an AFC circuit, a carrier recovery circuit and a receiver for use in satellite digital television broadcasting and more particularly to an AFC circuit, a carrier recovery circuit and a receiver for regenerating a carrier even at the time of low C/N ratio.</p>	<p>[0004] In a conventional transmission method of transmitting a modulated signal having many constellation points continuously or a method in which the number of constellation points is changed by time division system, if carrier recovery is carried out continuously, when the C/N ratio drops, a stabilized carrier recovery signal cannot be obtained in a modulation period having many constellation points. For this reason, even if a modulated signal having few constellation points exists, stable demodulation is disabled.</p>
<p>[SUMMARY OF THE INVENTION]</p>	<p>[0005] Further, in a method for carrying out carrier recovery periodically using only a period having a few constellation points for such a modulated signal, there is a problem that false lock occurs by observing the phase periodically. Therefore, a wide capture range cannot be achieved. Thus, because a very high frequency stabilization accuracy is demanded in the transmission system containing the frequency conversion portion, the receiver device becomes very expensive.</p>
<p>[0002] For digital transmission through a satellite, hierarchical transmission method capable of data transmission to some extent even at the time of a low C/N ratio by adaptive transmission by time division based on modulation method having different numbers of constellation points by considering a deterioration of the C/N ratio due to rain attenuation or the like has been invented. In such a transmission method, it is very difficult to obtain a reference signal necessary for carrier recovery from a period of modulation wave having many constellation points at the time of low C/N ratio, and therefore, a carrier recovery method which is an ordinary carrier recovery method for continuously regenerating the carrier, cannot be used.</p>	<p>[0006] For the reason, according to the method for transmitting modulated signals having different numbers of constellation points in time division system, if the conventional carrier recovery system is utilized, the carrier recovery is disabled when the C/N ratio is low.</p>
<p>[0003] Accordingly, an object of the present invention is to achieve carrier recovery by disposing periodically a modulated signal period with few constellation points which is modulated by, for example, BPSK modulation method or QPSK modulation method and from which a reference carrier signal having a considerable CN rate can be obtained, and fetching out phase/frequency error information periodically. Further, because, according to a method for observing a phase error signal periodically, with a frequency of a predetermined period, the same phase error signal is obtained, so-called false lock phenomenon in which the frequency is apparently synchronized with a different frequency from its proper carrier frequency occurs. To avoid this phenomenon, a modulated signal with few constellation points which is modulated by, for example, BPSK modulation method or QPSK modulation method is set at a predetermined interval and in the pseudo synchronising state, a frequency of a difference from the proper carried frequency is observed by using such a fact that the reception signal phase is rotated in a predetermined direction so as to control the VCO (Voltage Controlled Oscillator) thereby making it possible to synchronise with the proper frequency. In the modulation period having few constellation points, detection of the pseudo synchronising state and synchronisation with a desired frequency are enabled using a statistical characteristic of an observed signal.</p>	<p>[0007] Then, although a method for controlling the VCO or NCO (Numerical Controlled Oscillator) can be considered by measuring the phase with only a period having a few constellation points, there is a problem that a wide capture range cannot be achieved because of false lock phenomenon caused by observing the phase periodically.</p>
	<p>[0008] The present invention has been achieved in viewpoints of the above problems and therefore it is an object of the invention to provide an AFC circuit capable of regenerating a carrier signal synchronous with the inputted signal in terms of the frequency while preventing an occurrence of false lock even when a reference signal period or a modulated signal period having a few constellation points which can be used for carrier recovery, contained in an input signal, is short or even when noise is mixed in the inputted signal.</p>
	<p>[0009] Another object of the invention is to provide a carrier recovery circuit capable of regenerating the carrier signal stably in a wide capture range by transmitting modulations signal having different numbers of constellation points by time-division system and carrying out carrier synchronization using phase and frequency error information obtained periodically even if the C/N ratio is low when a modulated signal is received and regenerated.</p>
	<p>[0010] Still another object of the invention is to provide a receiver device capable of regenerating information contained in digitally modulated signal by carrying out carrier synchronization using phase and frequency error information obtained periodically and regenerating the carrier signal stably in a wide capture range even if</p>

the C/N ratio is low when digitally modulated signal provided with a reference signal period or digitally modulated signal period having a few constellation points to be useful for carrier recovery at a predetermined time interval is received and regenerated.

Disclosure of Invention

[0011] To achieve the above object, the AFC circuit described in claim 1 is an AFC circuit for detecting a frequency difference between two inputted signals and zeroing said frequency difference between the inputted signals according to the detection result, the AFC circuit comprising: a frequency difference detecting portion for detecting a phase difference between the inputted signals and generating a frequency correction signal according to the phase difference or a time differential value of the phase difference; and a frequency difference correcting portion for rotating the phase of the inputted signal according to the frequency correction signal outputted from the frequency difference detecting portion so as to zero the frequency difference between the inputted signals.

[0012] According to claim 1, in the AFC circuit for detecting a frequency difference between two inputted signals and zeroing the frequency difference between the inputted signals according to the detection result, a frequency difference detecting portion detects a phase difference between the inputted signals and generates a frequency correction signal according to the phase difference or a time differential value of the phase difference and a frequency difference correcting portion rotates phase of the inputted signals according to the frequency correction signal outputted from the frequency difference detecting portion so as to zero the frequency difference between the inputted signals. As a result, even when the reference signal period modulated signal period having few constellation points which is usable for regenerating a carrier contained in the inputted signals is short or even when noise is mixed in the inputted signals, a carrier signal synchronous with the inputted signals is regenerated while preventing an occurrence of false lock.

[0013] The AFC circuit described in claim 2 is an AFC circuit for detecting a frequency difference between two inputted signals and zeroing said frequency difference between the inputted signals according to the detection result, the AFC circuit comprising: a correlation computing portion for detecting a phase difference between the inputted signals and computing an autocorrelation coefficient of the phase difference; and a frequency difference correcting portion for counting a number of peaks in a waveform of the autocorrelation coefficient obtained by the correlation computing portion and rotating phase of the inputted signals according to the count result so as to zero the frequency difference between the inputted signals.

[0014] According to claim 2, in the AFC circuit for

detecting a frequency difference between two inputted signals and zeroing the frequency difference between the inputted signals according to the detection result, a correlation computing portion detects a phase difference between the inputted signals and computes an autocorrelation coefficient of the phase difference and a frequency difference correcting portion counts the number of peaks in a waveform of the autocorrelation coefficient obtained by the correlation computing portion and rotates phase of the inputted signals according to the count result so as to zero the frequency difference between the inputted signals. As a result, even when the reference signal period or modulated signal period having few constellation points which is usable for regenerating a carrier contained in the inputted signal is short or even when noise is mixed in the inputted signal, a carrier signal synchronous with the inputted signal is regenerated while preventing an occurrence of false lock.

[0015] The AFC circuit described in claim 3 is an AFC circuit for detecting a frequency difference between two inputted signals and zeroing said frequency difference between the inputted signals according to the detection result, the AFC circuit comprising: a correlation computing portion for detecting a phase difference between the inputted signals and computing an autocorrelation coefficient of a waveform varying in time of the phase difference; and a frequency difference correcting portion for obtaining an average period of a periodic waveform appearing in a waveform of the autocorrelation coefficient obtained by the correlation computing portion and rotating a phase between the inputted signals according to the average period so as to zero the frequency difference of the inputted signals.

[0016] According to claim 3, in the AFC circuit for detecting a frequency difference between two inputted signals and zeroing the frequency difference between the inputted signals according to the detection result, a correlation computing portion detects a phase difference between the inputted signals and computes an autocorrelation coefficient of a waveform varying in time of the phase difference and a frequency difference correcting portion obtains an average period of periodic waveform appearing in a waveform in the autocorrelation coefficient obtained by the correlation computing portion and rotates a phase between the inputted signals according to the average period so as to zero the frequency difference of the inputted signals. As a result, even when the reference signal period or modulated signal period having few constellation points which is usable for regenerating a carrier contained in the inputted signal is short or even when noise is mixed in the inputted signal, a carrier signal synchronous with the inputted signal is regenerated while preventing an occurrence of false lock.

[0017] The AFC circuit according to claim 4 is an AFC circuit for detecting a frequency difference between two inputted signals and zeroing said frequency difference

between the inputted signals according to the detection result, the AFC circuit comprising: a region determining portion for detecting a phase difference between the inputted signals and determining which region each signal point is included in according to the phase difference; and a frequency difference correcting portion for counting a determination result of the region determining portion for each phase and for each determining region rotated at a rotation speed corresponding to a set frequency, and rotating phase of the inputted signals according to the count result so as to zero the frequency difference between the inputted signals.

[0018] According to claim 4, in the AFC circuit for detecting a frequency difference between two inputted signals and zeroing the frequency difference between the inputted signals according to the detection result, a region determining portion detects a phase difference between the inputted signals and determines which region each signal point is included in according to the phase difference and a frequency difference correcting portion counts a determination result of the region determining portion for each phase and for each determining region rotated at a rotation speed corresponding to a set frequency and rotates phase of the inputted signals according to the count result so as to zero the frequency difference between the inputted signals. As a result, even when the synchronisation period for the inputted signal is short or even when noise is mixed in the inputted signal, a carrier signal synchronous with the inputted signal is regenerated while preventing an occurrence of false lock.

[0019] The carrier recovery circuit according to claim 5 is a carrier recovery circuit for regenerating a carrier signal from an I baseband signal and a Q baseband signal obtained by quadrature-demodulating a reception signal, the circuit comprising: a frequency difference detecting portion for detecting a phase difference between the regenerated carrier signal and the reception signal from the I axis side signal and the Q axis side signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal, and generating a frequency correction signal according to the phase difference or a differential value of the phase difference; and a frequency difference correcting portion for controlling a frequency of the regeneration carrier signal according to the frequency correction signal outputted from the frequency difference detecting portion so as to zero a frequency difference between the reception signal and the regeneration carrier signal.

[0020] According to claim 5, in the carrier recovery circuit for regenerating a carrier signal from an I baseband signal and a Q baseband signal obtained by quadrature-demodulating a reception signal, a frequency difference detecting portion detects a phase difference between the regenerated carrier signal and the reception signal from the I axis side signal and the Q axis side signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal and gener-

ates a frequency correction signal according to the phase difference or a differential value of the phase difference and a frequency difference correcting portion controls a frequency of the regenerated carrier signal according to the frequency correction signal outputted from the frequency difference detecting portion so as to zero a frequency difference between the reception signal and the regenerated carrier signal. As a result, upon transmitting a modulated signal having different numbers of constellation points by time division system and receiving the signal, even when the C/N ratio is low, the carrier synchronization is carried out using information of the phase and frequency obtained periodically, so that the carrier signal is regenerated stably in a wide capture range.

[0021] The carrier recovery circuit according to claim 6 is a carrier recovery circuit regenerating a carrier signal from an I baseband signal and a Q baseband signal obtained by quadrature-demodulating a reception signal, the circuit comprising: a correlation computing portion for detecting a phase difference between the regenerated carrier signal and the reception signal from the I axis side signal and the Q axis side signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal so as to compute autocorrelation coefficients of the phase difference; and a frequency difference correcting portion for counting peaks of the waveform of the autocorrelation coefficient waveform obtained by the correlation computing portion and controlling a frequency of the regenerated carrier signal according to the count result so as to zero the frequency difference between the reception signal and the regenerated carrier signal.

[0022] According to claim 6, in the carrier recovery circuit for regenerating a carrier signal from an I baseband signal and a Q baseband signal obtained by quadrature-demodulating a reception signal, a correlation computing portion detects a phase difference between the regenerated carrier signal and the reception signal from the I axis side signal and the Q axis side signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal so as to compute autocorrelation coefficients of the phase difference and a frequency difference correcting portion counts peaks of a waveform of the autocorrelation coefficient obtained by the correlation computing portion and controls frequency of the regeneration carrier signal according to the count result so as to zero the frequency difference between the reception signal and the regenerated carrier signal. As a result, upon transmitting a modulated signal having different numbers of constellation points by time division system and receiving the signal, even when the C/N ratio is low, the carrier synchronization is carried out using information of the phase and frequency obtained periodically, so that the carrier signal is regenerated stably in a wide capture range.

[0023] The carrier recovery circuit described in claim 7 is a carrier recovery circuit for regenerating a carrier

signal from an I baseband signal and a Q baseband signal obtained by quadrature-demodulating a reception signal, the circuit comprising: a correlation computing portion for detecting a phase difference between the regenerated carrier signal and the reception signal from the I baseband signal and the Q baseband signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal so as to compute autocorrelation coefficients of the phase difference; and a frequency difference correcting portion for obtaining an average period of a periodic waveform appearing in a waveform of the autocorrelation coefficient obtained by the correlation computing portion, and controlling a frequency of the regenerated carrier signal based on the average period so as to zero the frequency difference between the reception signal and the regenerated carrier signal.

[0024] According to claim 7, in the carrier recovery circuit for regenerating a carrier signal from an I baseband signal and a Q baseband signal obtained by quadrature-demodulating a reception signal, a correlation computing portion detects a phase difference between the regenerated carrier signal and the reception signal from the I baseband signal and the Q baseband signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal so as to compute the autocorrelation coefficients of the phase difference. A frequency difference correcting portion obtains an average period of a periodic waveform appearing in a waveform of the autocorrelation coefficient obtained by the correlation computing portion and controls frequency of the regenerated carrier signal based on the average period so as to zero the frequency difference between the reception signal and the regenerated carrier signal. As a result, upon transmitting a modulated signal having different numbers of constellation points by time division system and receiving the signal, even when the C/N ratio is low, the carrier synchronization is carried out using information of the phase and frequency obtained periodically, so that the carrier signal is regenerated stably in a wide capture range.

[0025] The carrier recovery circuit according to claim 8 is a carrier recovery circuit for regenerating a carrier signal from an I baseband signal and a Q baseband signal obtained by quadrature-demodulating a reception signal, the circuit comprising: a region determining portion for detecting a phase difference between the regenerated carrier signal and the reception signal from the I axis side signal and the Q axis side signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal, and determining which region of a phase plane each signal point is included in based on the phase difference; and a frequency difference/phase difference correcting portion for counting a determination result of the region determining portion for each phase and for each determination region rotated at a rotation speed corresponding to a set frequency, and controlling frequency and phase of the

regenerated carrier signal based on the count result so as to zero a frequency difference and the phase difference between the reception signal and the regenerated carrier signal.

5 [0026] According to claim 8, in the carrier recovery circuit for regenerating a carrier signal from an I baseband signal and a Q baseband signal obtained by quadrature-demodulating a reception signal, a region determining portion detects a phase difference between the regenerated carrier signal and the reception signal from the I axis side signal and the Q axis side signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal and determine which region of a phase plane each signal point is included in based on the phase difference and a frequency difference correcting portion counts a determination result of the region determining portion for each phase and for each determination region rotated at a rotation speed corresponding to a set frequency and controls frequency and phase of the regenerated carrier signal based on the count result so as to zero the frequency difference and phase difference between the reception signal and regenerated carrier signal. As a result, upon transmitting a modulated signal having different numbers of constellation points by time division system and receiving the signal, even when the C/N ratio is low, the carrier synchronization is carried out using information of the phase and frequency obtained periodically, so that the carrier signal is regenerated stably in a wide capture range.

30 [0027] The receiver device according to claim 9 is a receiver device for regenerating a carrier signal based on the I baseband signal and the Q baseband signal obtained by quadrature-demodulating a reception signal, and decoding the I baseband signal and the Q baseband signal so as to regenerate information, said receiver device further receiving a digitally modulated signal provided with a reference signal period or a digitally modulated signal period having few constellation points to be used for carrier recovery at a predetermined time interval; and establishing carrier synchronization using information about phase error and frequency error obtained in the reference signal period or in the digitally modulated signal period having constellation points.

35 [0028] According to claim 9, in the receiver device for regenerating a carrier signal based on the I baseband signal and the Q baseband signal obtained by quadrature-demodulating a reception signal, and decoding the I baseband signal and the Q baseband signal so as to regenerate information, the receiver device further receives a digitally modulated signal provided with a reference signal period or a digitally modulated signal period having few constellation points to be used for carrier recovery at a predetermined time interval and establishes carrier synchronization using information about phase error and frequency error obtained in the reference signal period of the digitally modulated signal

or the digitally modulated signal period. As a result, upon receiving a digitally modulated signal provided with a reference signal period or a digitally modulated signal period having a few constellation points useful for carrier recovery at a predetermined time interval, even when the C/N ratio is low, carrier synchronization is carried out using phase and frequency error information obtained periodically and then a carrier signal is regenerated stably in a wide capture range so as to regenerate information contained in digitally modulated signal.

[0029] The receiver device according to claim 10 is a receiver device for regenerating a carrier signal based on the I baseband signal and the Q baseband signal obtained by quadrature-demodulating a reception signal, and decoding the I baseband signal and the Q baseband signal so as to regenerate information, said receiver device further receiving a digitally modulated signal provided with a reference signal period or a digitally modulated signal period having few constellation points to be used for carrier recovery at a predetermined time interval; and detecting a difference between a regeneration carrier frequency and a carrier frequency of the reception signal obtained in a reference signal period or in a digitally modulated signal period having few constellation points so as to achieve at least one of AFC function or false lock preventing function based on the detection result.

[0030] According to claim 10, in the receiver device for regenerating a carrier signal based on the I baseband signal and the Q baseband signal obtained by quadrature-demodulating a reception signal, and decoding the I baseband signal and the Q baseband signal so as to regenerate information, the receiver device further receives a digitally modulated signal provided with a reference signal period or a digitally modulated signal period having few constellation points to be used for carrier recovery at a predetermined time interval and detecting a difference between the regenerated carrier frequency and the carrier frequency of the reception signal obtained in a reference signal period of the digitally modulated signal or a digitally modulated signal period so as to achieve at least one of AFC function or false lock preventing function based on the detection result. As a result, upon receiving a digitally modulated signal provided with a reference signal period or with a digitally modulated signal period having a few constellation points useful for carrier recovery at a predetermined time interval, even when the C/N ratio is low, carrier synchronization is carried out using phase and frequency error information obtained periodically and then a carrier signal is regenerated stably in a wide capture range so as to regenerate information contained in digitally modulated signal.

[0031] The receiver device according to claim 11 is a receiver device according to claim 10 wherein a regeneration carrier frequency is controlled according to detuning frequency information obtained by time differential value or a primary inclination of a change of a

phase obtained by observing a phase variation in a reference signal period of a reception signal or in a modulated signal period having few constellation points, under a state of frequency asynchronization.

5 [0032] According to claim 11, in the receiver device according to claim 10, a regeneration carrier frequency is controlled according to detuning frequency information obtained by time differential value or a primary inclination of a change of a phase obtained by observing a phase variation in a reference signal period of a reception signal or in a modulated signal period having few constellation points, under a state of frequency asynchronization. As a result, upon receiving a digitally modulated signal provided with a reference signal period or a digitally modulated signal period having a few constellation points useful for carrier recovery at a predetermined time interval, even when the C/N ratio is low, carrier synchronization is carried out using phase and frequency error information obtained periodically and then a carrier signal is regenerated stably in a wide capture range so as to regenerate information contained in digitally modulated signal.

10 [0033] The receiver device according to claim 12 is a receiver device according to claim 10 wherein a detuning frequency is estimated based on periodicity of an autocorrelation coefficient waveform in a phase variation curve obtained by observing a phase variation in a reference signal period of a reception signal or in a modulated signal period having few constellation points and then a regeneration carrier frequency is controlled based on detuning frequency information obtained by the estimation operation, under a state of frequency asynchronization.

15 [0034] According to claim 12, in the receiver device according to claim 10, a detuning frequency is estimated based on periodicity of an autocorrelation coefficient waveform in a phase variation curve obtained by observing a phase variation in a reference signal period of a reception signal or a modulated signal period having few constellation points and then a regeneration carrier frequency is controlled based on detuning frequency information obtained by the estimation operation. As a result, upon receiving a digitally modulated signal provided with a reference signal period or a digitally modulated signal period having a few constellation points useful for carrier recovery at a predetermined time interval, even when the C/N ratio is low, carrier synchronization is carried out using phase and frequency error information obtained periodically and then a carrier signal is regenerated stably in a wide capture range so as to regenerate information contained in digitally modulated signal.

20 [0035] The receiver device according to claim 13 is a receiver device according to claim 12 wherein the regeneration carrier frequency is set at a low frequency preliminarily so as to provide a frequency of a waveform or a number of correlation peaks appearing in the autocorrelation coefficient waveform relative to a desired fre-

quency with an offset, thereby making it possible to estimate a detuning frequency lower than the desired frequency.

[0036] According to claim 13, in the receiver device according to claim 12, the regeneration carrier frequency is set at a low frequency preliminarily so as to provide a frequency of a waveform or the number of correlation peaks appearing in an autocorrelation coefficient waveform relative to a desired frequency with an offset, thereby making it possible to estimate a detuning frequency lower than a desired frequency. As a result, upon receiving a digitally modulated signal provided with a reference signal period or a digitally modulated signal period having a few constellation points useful for carrier recovery at a predetermined time interval, even when the C/N ratio is low, carrier synchronization is carried out using phase and frequency error information obtained periodically and then a carrier signal is regenerated stably in a wide capture range so as to regenerate information contained in digitally modulated signal.

[0037] The receiver device according to claim 14 is a receiver device according to claim 12 wherein whether or not carrier synchronization is established is detected based on a statistical characteristic of phase points of a signal in a modulation period having few constellation points and oscillation frequency sweep of a local oscillator for use for frequency conversion is stopped based on the detection result.

[0038] According to claim 14, in the receiver device according to claim 12, whether or not carrier synchronization is established is detected based on a statistical characteristic of phase point of a signal in a modulation period having few constellation points and oscillation frequency sweep of a local oscillator for use for frequency conversion is stopped based on the detection result. As a result, upon receiving a digitally modulated signal provided with a reference signal period or a digitally modulated signal period having a few constellation points useful for carrier recovery at a predetermined time interval, even when the C/N ratio is low, carrier synchronization is carried out using phase and frequency error information obtained periodically and then a carrier signal is regenerated stably in a wide capture range so as to regenerate information contained in digitally modulated signal.

[0039] The receiver device according to claim 15 is a receiver device for regenerating a carrier signal based on the I baseband signal and the Q baseband signal obtained by quadrature-demodulating a reception signal, and decoding the I baseband signal and the Q baseband signal so as to regenerate information, said receiver device further including a carrier recovery circuit comprising: a receiving portion for receiving a digitally modulated signal provided with a reference signal period or with a digital modulation period having few constellation points to be used for carrier recovery at a predetermined time interval so as to obtain the reception signal; a region determining portion for detecting a

phase difference between the regenerated carrier signal and the reception signal from the I axis side signal and the Q axis side signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal, and determining which region of a phase plane each signal point is included in based on the phase difference; and a frequency difference/phase difference correcting portion for counting a determination result of the region determining portion for each phase and for each determination region rotated at a rotation speed corresponding to a set frequency, and controlling frequency and phase of the regenerated carrier signal based on the count result so as to zero a frequency difference and the phase difference between the reception signal and the regenerated carrier signal, whereby at least one of AFC function or false lock preventing function being achieved.

[0040] According to claim 15, in the receiver device for regenerating a carrier signal based on the I baseband signal and the Q baseband signal obtained by quadrature-demodulating a reception signal, and decoding the I baseband signal and the Q baseband signal so as to regenerate information, the receiver device further includes a carrier recovery circuit comprising a receiving portion for receiving a digitally modulated signal provided with a reference signal period or with a digital modulation period having few constellation points to be used for carrier recovery at a predetermined time interval, a region determining portion for detecting a phase difference between the regenerated carrier signal and the reception signal from the I axis side signal and the Q axis side signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal and determining which region of a phase plane each signal point is included in based on the phase difference, a frequency difference/phase difference correcting portion for counting a determination result of the region determining portion for each phase and for each determination region rotated at a rotation speed corresponding to a set frequency, and controlling frequency and phase of the regeneration carrier signal based on the count result so as to zero the frequency difference and phase difference between the reception signal and regenerated carrier signal, whereby at least one of AFC function or false lock preventing function being achieved. As a result, upon receiving a digitally modulated signal provided with a reference signal period or a digitally modulated signal period having a few constellation points useful for carrier recovery at a predetermined time interval, even when the C/N ratio is low, carrier synchronization is carried out using phase and frequency error information obtained periodically and then a carrier signal is regenerated stably in a wide capture range so as to regenerate information contained in digitally modulated signal.

Brief Description of Drawings

[0041]

Fig. 1 is a schematic diagram showing an example of format of digital signal for use in an embodiment of an AFC circuit, a carrier recovery circuit and a receiver device of the present invention;
 Fig. 2 is a block diagram showing an example of a receiver circuit for use in an embodiment of the AFC circuit, carrier recovery circuit and receiver device of the present invention;
 Fig. 3 is a block diagram showing an example of a concrete structure of a fine control AFC circuit shown in Fig. 1;
 Fig. 4 is a schematic diagram showing an example of relation between the phase of BPSK signal to be inputted into the fine control AFC circuit shown in Fig. 3 and each quadrant;
 Fig. 5 is a waveform diagram showing an example of a phase error signal outputted from a phase detecting circuit shown in Fig. 3;
 Fig. 6 is a block diagram showing an example of a carrier phase/frequency synchronization detecting circuit for use in the present invention;
 Fig. 7 is a schematic diagram showing a relational example between the phases of I baseband signal and Q baseband signal to be inputted into a measuring region setting circuit shown in Fig. 6 and the measuring region;
 Fig. 8 is a block diagram showing an example of a fine control AFC circuit of autocorrelation function method, of other fine control AFC circuit for use as a fine control AFC circuit shown in Fig. 2;
 Fig. 9 is a block diagram showing another example of a fine control AFC circuit of auto-correlation function method, of other fine control AFC circuit for use as a fine control AFC circuit shown in Fig. 2;
 Figs. 10A-C are schematic diagrams showing a basic principle of the count type fine control AFC circuit, of other fine control AFC circuits for use as a fine control AFC circuit shown in Fig. 2;
 Fig. 11 is a schematic diagram showing an example of the count type fine control AFC circuit, of other fine control AFC circuits for use as a fine control AFC circuit shown in Fig. 2; and
 Fig. 12 is a block diagram showing a further example of the fine control AFC circuit of the auto-correlation function type of other fine control AFC circuits for use as a fine control AFC circuit shown in Fig. 2.

Best Mode for Carrying Out the Invention

((Basic Description of the Invention))

[0042] Prior to a detailed description of an AFC circuit, a carrier recovery circuit and a receiver device of the present invention, first of all, the basic principle of the

AFC circuit, carrier recovery circuit and receiver unit of the present invention will be described.

[0043] Generally, if a conventional carrier recovery method is used as a transmission scheme for transmitting modulated signals each having different numbers of constellation points in time division multiplexing scheme, carrier recovery is difficult at the time of a low C/N ratio. Therefore, according to the present invention, carrier recovery is carried out as described below.

[0044] That is, in an AFC circuit, carrier recovery circuit and receiver unit of the present invention, the phase of a signal is measured using only a period containing a small quantity of constellation points and VCO or NCO (Numerical Controlled Oscillator) is controlled so as to carry out stable carrier recovery even at the time of a low C/N ratio. However, because in this case, the phase difference between the received modulated signal and regenerated carrier signal is measured periodically, there is a possibility that false lock phenomenon occurs, so that the wide capture range cannot be realized.
 [0045] Thus, a SYNC with relatively short period, modulated by an already-known pattern, is assigned into the modulation wave and the oscillation frequency of the VCO or NCO is swept in a wide range, for example, 2 MHz range. The sweeping is stopped at a frequency in which the SYNC can be received and coarse control AFC is carried out. A period containing a small quantity of the constellation points (for example, BPSK signal interval) and having some length is provided in the modulation wave. A difference (difference of frequency) between a frequency of the received modulated signal and a frequency of VCO or NCO local oscillation signal is obtained in this period and then the frequency difference is analyzed according to phase differential function method, self-relative function method or count type method. By controlling the VCO or NCO based on this result of analysis, an AFC function having a wide capture range is realized and even at the time of low C/N ratio, occurrence of the false lock phenomenon is suppressed to realize the wide frequency capture range so as to regenerate an accurate carrier signal.

((Embodiments for Carrying Out the Invention))

[0046] Fig. 1 is a schematic diagram showing an example of format for a digital transmission signal for use in an embodiment of the AFC circuit, carrier recovery circuit and receiver device of the present invention which use the above mentioned basic principle.

[0047] In the digital transmission signal shown in this Figure, a single frame is composed of a plurality of blocks, each of which comprises a signal D which is multi-valued signal period and a signal C which is BPSK signal period to be used for carrier phase synchronization, except its head block.

[0048] Assuming that the quantity of symbols in a single block is, for example, 196 symbols, in a first block of those blocks, for example, 20 symbols at the head por-

tion are SYNC (synchronous signal) subjected to BPSK modulation by UW (unique word) and 176 (196-20 = 176) symbols following this SYNC are information to be transmitted which is subjected to BPSK modulation.

[0049] Further, in each block of second and following blocks, for example, up to 192 symbols from a first symbol is information which should be transmitted and subjected to QPSK modulation or 8PSK modulation and the last four symbols are information which should be transmitted and subjected to BPSK modulation for phase synchronization.

[0050] Fig. 2 is a block diagram showing an example of a receiver circuit for use in an embodiment of the AFC circuit, carrier recovery circuit and receiver device of the present invention for receiving the aforementioned digital transmission signal.

[0051] A receiver circuit 1 shown in this diagram comprises an antenna 2 for receiving a digital transmission signal of the format shown in Fig. 1, ODU 3 for converting the digitally modulated signal received by this antenna 2 in terms of frequency so as to generate an IF signal, a coarse control AFC block 4 which quadrature-demodulates the IF signal outputted from the ODU 3 so as to generate in-phase axis (hereinafter referred to as I axis) side baseband signal and an quadrature axis (hereinafter referred to as Q axis) side baseband signal and sweeps from a low frequency side in, for example, 2 MHz range so as to detect a first block SYNC contained in the I baseband signal and Q baseband signal, a fine control AFC block 5 which detects a detuning frequency depending on changes of phase observed in a period of the first block SYNC and subsequent 176 symbol BPSK signal contained in the I baseband signal and Q baseband signal to be outputted from this coarse control AFC block 4 so as to regenerate a fine controlled carrier signal, and an APC block 6 for detecting a fine deviation of the frequency and phase error of the I baseband signal and Q baseband signal using the BPSK signal period of each block of the I baseband signal and Q baseband signal outputted from this fine control AFC block 5.

[0052] When a digital transmission signal is received by the antenna 2 and the IF signal is outputted from the ODU 3, the coarse control AFC block 4 quadrature-demodulates the IF signal so as to generate the I baseband signal and Q baseband signal. To detect SYNC of the first block contained in the aforementioned I baseband signal and Q baseband signal, local oscillation frequency sweep is carried out from a low frequency side, in a range of, for example, 2 MHz so as to regenerate coarsely controlled carrier signal of the IF signal. At the same time, a detuning frequency is detected according to the SYNC of the first block and subsequent 176 symbol BPSK signal contained in the aforementioned I baseband signal and Q baseband signal by the fine control AFC block 5 so as to regenerate fine controlled carrier signal of the I baseband signal and Q baseband signal. Then, according to the BPSK signal of each

block of the I baseband signal and Q baseband signal outputted from the fine control AFC block 5, the APC block 6 adjusts the phase of the regenerated carrier signal to control the phases of the I baseband signal and Q baseband signal. Then, the I baseband signal and Q baseband signal obtained thereby having no deviation in frequency and phase are supplied to a signal decoding portion (not shown).

[0053] The coarse control AFC block 4 comprises a sweep generator circuit 7 which contains a variable frequency oscillator such as VCO or NCO and if no SYNC detection signal is inputted, generates a local oscillation signal while sweeping the VCO or NCO oscillation frequency in a range of, for example, 2 MHz from a low frequency side and which when the SYNC detection signal is inputted, stops the sweep, a quadrature demodulation circuit 8 which quadrature-demodulates the IF signal outputted from the ODU 3 using the local oscillation signal outputted from the sweep generator 7 so as to generate the I baseband signal and Q baseband signal, a Nyquist filter circuit 9 for carrying out image removal and waveform shaping by providing Nyquist characteristic to the I baseband signal outputted from the quadrature demodulation circuit 8, an A/D conversion circuit 11 for A/D conversion of the I baseband signal outputted from the Nyquist filter circuit 9 so as to generate a digitized I baseband signal, a Nyquist filter circuit 10 for carrying out image removal and waveform shaping by supplying Nyquist characteristic to the Q baseband signal outputted from the quadrature demodulation circuit 8, an A/D conversion circuit 12 for A/D conversion of the Q baseband signal outputted from the Nyquist filter circuit 10 so as to generate digitized Q baseband signal, and a frame synchronization detecting circuit 13 which compares data contained in the I baseband signal and Q baseband signal outputted from the A/D conversion circuits 11, 12 with preliminarily registered unique word (same unique word as unique word for use in SYNC of digital transmission signal) and when data coinciding with the unique word is detected, generates SYNC detection signal indicating that the SYNC of the first block has been detected and supplies this to the sweep generator 7.

[0054] In asynchronous state in which the carrier of the digital transmission signal is not regenerated, like just after the power of the receiver circuit 1 is turned on, the oscillation frequency is swept from a low frequency side in a range of, for example, 2 MHz and according to the local oscillation signal whose frequency is swept, the IF signal outputted from the ODU 3 is quadrature-demodulated so as to generate the I baseband signal and Q baseband signal. Then, by providing the I baseband signal and Q baseband signal with the Nyquist characteristic, image removable and waveform shaping are carried out. After that, those signals are digitized and supplied to the fine control AFC block 5. Further, in parallel to this operation, when data obtained from the I baseband signal and Q baseband signal digitized coin-

cides with unique word, the SYNC detection signal indicating that the SYNC in the top of each frame has been detected is generated and then the oscillation frequency at this time is fixed. Using the local oscillation signal of this oscillation frequency as coarsely controlled carrier signal, the IF signal quadrature demodulation operation, Nyquist filter characteristic providing operation and A/D conversion operation are continued. Then, the digitized I baseband signal and Q baseband signal obtained thereby are supplied to the fine control AFC block 5.

[0055] At this time, because in the digital transmission signal received by the receiver circuit 1, the SYNC is BPSK-modulated according to an already-known pattern (unique word), the SYNC can be detected even at the time of low C/N ratio within a frequency error of some extent, even if carrier synchronization is not established. Then, the carrier synchronization can be established within the frequency error of some extent with this SYNC detection as a reference.

[0056] The fine control AFC block 5 contains a fine control AFC circuit 14 for carrying out fine adjustment of the frequencies of the I baseband signal and Q baseband signal according to the digitized I baseband signal and Q baseband signal outputted from the coarse control AFC block 4. A detuning frequency is detected from the SYNC of the first block and subsequent 176 symbol BPSK signal contained in the I baseband signal and Q baseband signal outputted from the coarse control AFC block 4. Then, the frequency of the I baseband signal and the frequency of the Q baseband signal are adjusted finely while the fine adjustment carrier signals of the I axis aide baseband signal and Q baseband signal are regenerated and then supplied to the APC block 6 in a state in which the frequency deviation is reduced to almost zero.

[0057] In this case, as shown in Fig. 3, the fine control AFC circuit 14 comprises an NCO circuit 15 which changes and fixes the oscillation frequency depending on an inputted frequency difference signal, a phase rotation circuit 16 for carrying out complex frequency conversion by rotating the phase of the digitized I baseband signal and Q baseband signal outputted from the coarse control AFC block 4 according to the local oscillation signal outputted from the NCO circuit 15, a phase detection circuit 17 which computes arc tangent of the amplitude of the Q baseband signal divided by amplitude of the I baseband signal outputted from this phase rotation circuit 16 so as to generate a phase difference signal, a differential circuit 18 for generating a frequency difference signal by differentiating a phase difference signal outputted from this phase detecting circuit 17, and a filter circuit 19 which removes noise and unnecessary high frequency components contained in the frequency difference signal outputted from this differential circuit 18 and then supplies the signal to the NCO circuit 15 thereby controlling the frequency of the local oscillation signal outputted from the NCO circuit 15.

[0058] Then, first of all, the local oscillation signal is

used as the fine controlled carrier signal so as to rotate the phase of digitized I baseband signal and Q baseband signal outputted from the coarse control AFC block 4. Arc tangent of the amplitude of the Q baseband signal whose frequency has been adjusted, divided by the amplitude of the I baseband signal whose frequency has been adjusted is computed so as to generate a phase difference signal, while the I baseband signal whose frequency has been adjusted and Q baseband signal are supplied to the APC block 6. Then, this phase difference signal is differentiated so as to generate a frequency difference signal. Then, to zero this frequency difference signal value, the frequency of the local oscillation signal is adjusted so that the frequency difference signal value is zeroed.

[0059] Because in the digital transmission signal received from this receiver circuit 1, as shown in Fig. 4, the BPSK signal contained in a block is of such a transmission system in which the signal phase value is 0 or 180°. Thus, the second quadrant and third quadrant are turned by 180° so as to overlap them on the fourth and first quadrants, respectively. Accordingly, phase uncertainty due to modulation can be removed. If there is a frequency difference (there is detuning in carrier frequency) between the carrier signal used in generating the digital transmission signal and carrier signal regenerated on the receiver circuit 1 side, the value of the phase error signal observed in this coordinate system increases with a progress of time, so that a phase error signal (phase difference signal) having a waveform shown in Fig. 5 for example, is observed. Then, because the inclination of this phase error signal, that is, a time differential value is proportional to the frequency difference, the detuning frequency is detected by observing this inclination. Accordingly even if the digitized I baseband signal and Q baseband signal to be outputted from the coarse control AFC block 4 contain some extent of the frequency deviation, the frequency deviation of the I baseband signal and Q baseband signal can be zeroed.

[0060] The APC block 6 comprises an NCO circuit 20 for generating a local oscillation signal necessary for removing fine frequency error and phase error and changing and fixing the oscillation frequency depending on the value of an inputted phase error signal, a phase control phase rotation circuit 21 for rotating the phase determined by the I baseband signal and Q baseband signal having almost zeroed frequency deviation, outputted from the fine control AFC block 5 according to the local oscillation signal outputted from this NCO circuit 20, a phase detection circuit 22 for computing arc tangent of the amplitude of the BPSK signal of each block contained in the Q baseband signal whose phase has been adjusted, divided by the amplitude of the BPSK signal of each block contained in the I baseband signal whose phase has been adjusted, those signals being outputted from this phase control phase rotation circuit 21, so as to generate the phase error signal, and

a filter circuit 23 which removes noise contained in the phase error signal outputted from this phase detection circuit 22, then supplies the signal to the NCO circuit 20 and thus controls the frequency and phase of the local oscillation signal outputted from the NCO circuit 20.

[0061] Then, arc tangent of the amplitude of the BPSK signal of each block contained in the Q baseband signal whose frequency deviation has been almost zeroed, divided by the amplitude of the BPSK signal of each block contained in the I baseband signal whose frequency deviation has been almost zeroed, those signals being outputted from the fine control AFC block 5, is computed so as to generate the phase error signal. After that, the noise component of this phase error signal is removed and at the same time, the local oscillation signal is generated so that this phase error signal is zeroed. Then, the phase of the I baseband signal and Q baseband signal whose frequency deviation has been almost zeroed, those signals being outputted from the fine control AFC block 5, is rotated, and the phase and frequency of the local oscillation signal are adjusted so as to zero the value of the phase error signal, and then the phases of the I baseband signal and Q baseband signal whose frequency deviation has been almost zeroed, those signals being outputted from the fine control AFC block 5, are adjusted. Then, the I baseband signal and Q baseband signal whose phase has been adjusted are supplied to the signal decoding portion.

[0062] As a result, even if the I baseband signal and Q baseband signal outputted from the fine control AFC block 5 contain minute frequency error, this is detected and a its slight frequency error and slight phase error are corrected so as to establish a complete carrier synchronization.

[0063] If required, a carrier phase/frequency synchronization detecting circuit 24 shown in Fig. 6 is connected to each output terminal of the coarse control AFC block 4, each output terminal of the fine control AFC block 5 or each output terminal of the APC block 6 so as to check whether or not the regenerated carrier signal is locked.

[0064] The carrier phase/frequency synchronization detecting circuit 24 shown in this Figure comprises a measuring region setting circuit 25 for extracting a pulse signal in a measuring region of a phase plane shown by oblique lines of Fig. 7, of pulse signals in the BPSK modulation period contained in the I baseband signal and Q baseband signal outputted from any of the coarse control AFC block 4, fine control AFC block 5 or APC block 6; a counter circuit 26 for counting a pulse signal outputted from this measuring region setting circuit 25; a counter circuit 27 for counting the number of pulses of symbol clock signal indicating the number of symbols in the BPSK modulation period; a dividing circuit 28 for computing a ratio of a count result of the aforementioned counter circuit 27 as denominator to a count result of the aforementioned counter circuit 26 as numerator so as to obtain a result of division as informa-

tion saying that data in the BPSK modulation period is received properly; a threshold setting circuit 29 for outputting a threshold for synchronization determination for frequency and phase set preliminarily; and a comparison circuit 30 for comparing the threshold value outputted from this threshold setting circuit 29 with a result of division outputted from the division circuit 28, determining whether or not there is a frequency error in the I baseband signal and Q baseband signal inputted into the measuring region setting circuit 25 according to this comparison result and generating a phase/frequency synchronization detecting signal according to this determination result.

[0065] When the input terminal of the measuring region setting circuit 25 is connected to any of each output terminal of the coarse control AFC block 4, each output terminal of the fine control AFC block 5 of each output terminal of the APC block 6 and the I baseband signal and Q baseband signal are outputted from any of the coarse control AFC block 4, the fine control AFC block 5 and APC block 6, a pulse signal within the measuring region is extracted from pulse signals in the BPSK modulation period contained in the I baseband signal and Q baseband signal, the number of pulse signals is counted while the quantity of symbols in the BPSK modulation period is counted, it is determined whether or not there is any frequency error or phase error in the I baseband signal and Q baseband signal inputted into the measuring region setting circuit 25 according to a relation between a ratio of each count result obtained by each counting operation and the threshold value set preliminarily, and a phase/frequency synchronization detecting signal is generated according to this determination result.

[0066] If there is a frequency error in the I baseband signal and Q baseband signal inputted into the measuring region setting circuit 25, and the phase of the I and Q baseband signals is rotating, a probability that the pulse signal in the BPSK modulation period exists within the measuring region shown in Fig. 7 is almost equal to a probability that it exists out of the measuring region and a result of division outputted from the division circuit 28 becomes almost 0.5. Thus, it is determined that carrier synchronization has not been established. If the carrier synchronization of the I baseband signal and Q baseband signal inputted into the measuring region setting circuit 25 is established and the phases of the I baseband signal and Q baseband signal are fixed to almost 0 or 180°, the probability that the pulse signal in the BPSK modulation period exists in the measuring region shown in Fig. 7 is 100% and the probability that it exists out of the measuring region is almost 0%. A result of division outputted from the division circuit 28 is almost 1.0. Thus, it is determined that the carrier synchronization has been established.

[0067] According to this embodiment, when a digital transmission signal is received by the antenna 2 and the IF signal is outputted from the ODU 3, the IF signal is

quadrature-demodulated in the coarse control AFC block 4 so as to generate the I baseband signal and Q baseband signal. Local oscillation frequency sweep is carried out so as to detect the SYNC in a first block contained in the I baseband signal and Q baseband signal from a low frequency side in a range of, for example, 2 MHz so as to regenerate the coarsely controlled carrier signal of the IF signal. At the same time, using the SYNC of the first block and a period of subsequent 176 symbol BPSK signal contained in the I baseband signal and Q baseband signal, a detuning frequency is detected by the fine control AFC block 5 so as to regenerate the fine controlled carrier signals of the I baseband signal and Q baseband signal. Further, according to the BPSK signal of each block of the I baseband signal and Q baseband signal outputted from the fine control AFC block 5, a phase error of the regeneration carrier signal is detected so as to control the phases of the I baseband signal and Q baseband signal by the APC block 6. The I baseband signal and Q baseband signal obtained thereby are supplied to the signal decoding portion. Therefore, when a digitally modulated signal having a reference signal period or digitally modulated signal period having few constellation points for carrier recovery at a predetermined time interval is received, carrier synchronization is carried out using information of phase and frequency errors obtained periodically. As a result, the carrier signal is regenerated stably in a wide capture range so as to regenerate information contained in digitally modulated signal.

[0068] Then, carrier recovery having a wide capture characteristic can be achieved even at the time of a low CN. Therefore, in digital satellite broadcasting, use of a cheap frequency converter which has some frequency drift and phase noise is enabled so that the cost of the receiver device can be reduced largely.

((Other Embodiments))

[0069] Although according to the above described embodiment, the circuit employing differential function system shown in Fig. 3 is used as the fine control AFC circuit 14 so as to simplify the hardware structure, it is permissible to achieve the AFC function by analyzing a frequency error by self-correlation function system or count system as well as such differential function system and control the VCO or NCO based on this result of analysis.

[0070] In this case, when the autocorrelation function type fine control AFC circuit is used as the fine control AFC circuit 14, for example, the fine control AFC circuit 31 shown in Fig. 8 or the fine control AFC circuit 32 shown in Fig. 9 is used.

[0071] The fine control AFC circuit 31 shown in Fig. 8 comprises an NCO circuit 33 for generating a local oscillation signal of about 500kHz lower frequency and changing/fixing the oscillation frequency depending on the inputted frequency difference signal, a phase rotation

5 circuit 34 for rotating the phases of the digitized I baseband signal and Q baseband signal outputted from the coarse control AFC block 4 according to the local oscillation signal outputted from the NCO circuit 33, a phase detection circuit 35 for computing arc tangent of the amplitude of the Q baseband signal whose phase has been adjusted, divided by the amplitude of the I baseband signal whose phase has been adjusted, those signals being outputted from this phase rotation 10 circuit 34 so as to generate a phase difference signal, a correlation computing circuit 36 for generating a correlation coefficient signal to obtain an autocorrelation coefficient of the phase difference signal outputted from the phase detection circuit 35, an integration circuit 37 for 15 integrating some frames of the correlation coefficient signals outputted from the correlation computing circuit 36, using time series addition method such as average integration method by inter-frame addition so as to reduce an influence of noise, and a counter circuit 38 for counting the number of correlation peaks of the correlation coefficient signal waveform outputted from this integration circuit 37, and generating a frequency difference signal based on this count result so as to control the frequency of a local oscillation signal outputted from the NCO circuit 33.

[0072] Then, first of all, a local oscillation signal of, for example, 500 kHz lower frequency is used as the fine controlled carrier signal and the phases of the digitized I baseband signal and Q baseband signal outputted from the coarse control AFC block 4 are rotated. While the I baseband signal and Q baseband signal, whose phases have been adjusted, are supplied to the APC block 6, arc tangent of the amplitude of the Q baseband signal divided by the amplitude of the I baseband signal, whose phases have been adjusted, is computed so as to generate a phase difference signal. After that, self-correlation of this phase difference signal is obtained so as to generate a correlation coefficient signal. A number of correlation peaks of this correlation coefficient signal waveform is counted so as to generate a frequency difference signal. Then, the frequency of the local oscillation signal is adjusted so that the value of this frequency difference signal is zeroed. When the frequency difference signal is zeroed, the frequency of the local oscillation signal is fixed.

[0073] If there is a frequency difference between the carrier signal used in generating a digital transmission signal and a carrier signal regenerated on the receiver circuit 1 (if there is detuning in the carrier frequency), the value of a phase error signal observed in the coordinate system shown in Fig. 4 changes with a passage of time, so that a phase error signal having a waveform shown in Fig. 5 is observed. Because the number of correlation peaks appearing in the autocorrelation coefficient waveform of this phase error signal is proportional to the frequency difference, a detuning frequency is detected by observing the autocorrelation coefficient signal of the phase error signal. Even if the digitized I

baseband signal and Q baseband signal outputted from the coarse control AFC block 4 includes some extent of frequency deviation, the frequency deviation of the I baseband signal and Q baseband signal can be zeroed.

[0074] The fine control AFC circuit 32 shown in Fig. 9 comprises an NCO circuit 39 for generating a local oscillation signal of about 500 kHz lower frequency and changing/fixing the oscillation frequency depending on inputted frequency difference signal; a phase rotation circuit 40 for rotating the phases of the digitized I baseband signal and Q baseband signal outputted from the coarse control AFC block 4 according to the local oscillation signal outputted from this NCO circuit 39; a phase detecting circuit 41 for computing arc tangent of the amplitude of the Q baseband signal divided by the amplitude of the I baseband signal, whose phases have been adjusted, so as to generate a phase difference signal; a correlation computing circuit 42 for obtaining an autocorrelation coefficient of the phase difference signal outputted from this phase detecting circuit 41 so as to generate the correlation coefficient signal; an integration circuit 43 for integrating some frames of the correlation coefficient signal outputted from this correlation computing circuit 42 by using time series addition method such as average integration method by inter-frame addition; and an average period detecting circuit 44 for obtaining an average period of the periodic waveform appearing in the correlation coefficient signal outputted from the integration circuit 43 so as to control the frequency of the local oscillation signal outputted from the NCO circuit 39.

[0075] First of all, using the local oscillation signal of, for example, 500 kHz lower frequency as the fine controlled carrier signal, the phases of the digitized I baseband signal and Q baseband signal, those signals being outputted from the coarse control AFC block 4 are rotated. Then, the I baseband signal and Q baseband signal, whose phases have been adjusted, are supplied to the APC block 6 and arc tangent of the amplitude of the Q baseband signal whose phase has been adjusted, divided by the amplitude of the I baseband signal whose phase has been adjusted is computed so as to generate a phase difference signal. After that, an autocorrelation coefficient of this phase difference signal is obtained and the correlation coefficient signal is generated. At the same time, an average period of the periodic waveform appearing in this correlation coefficient signal is obtained so as to generate a frequency difference signal. The frequency of the local oscillation signal is adjusted so that the value of this frequency difference signal is zeroed. When the value of the frequency difference signal is zeroed, the frequency of the local oscillation signal is fixed.

[0076] As the same as the fine control AFC circuit 31 shown in Fig. 8, if there is a frequency difference between the carrier signal used in generating the digital transmission signal and a carrier signal regenerated at the receiver circuit 1 (if there is a detuning in the carrier

frequency), the value of an observed phase error signal changes with a passage of time in the coordinate system shown in Fig. 4, so that a phase error signal having a waveform shown in Fig. 5 is observed. The period of a periodic waveform appearing in the autocorrelation coefficient signal of this phase error signal is inversely proportional to the frequency difference, accordingly, by observing this correlation coefficient signal, a detuning frequency is detected. Even if the digitized I baseband signal and Q baseband signal, those signals being outputted from the coarse control AFC block 4, contain some amount of the frequency deviation, the frequency deviation of the I baseband signal and Q baseband signal can be zeroed.

[0077] Further, by using such self-correlation function, even if the C/N ratio of a received digital transmission signal is lower, accurate fine controlled carrier signals can be regenerated stably.

[0078] In the fine control AFC circuit using count method, the frequency difference is analyzed using the following basic principle, and the VCO or NCO is controlled based on this result of analysis so as to achieve an AFC function having a wide capture range.

[0079] If the frequency and phase of the BPSK signal contained in a digital transmission signal are synchronous with the frequency and phase of the regenerated carrier signal, even if noise is contained in the signal, most of signals are observed in a measuring region in signal space indicated by oblique lines of Fig. 10A.

[0080] On the other hand, if the frequency of the regenerated carrier signal is deviated, the signal point rotates with a passage of time. At this time, if the frequency of a carrier signal regenerated on the receiver circuit 1 side is lower than the carrier frequency of the BPSK signal contained in the digital transmission signal, by rotating the measuring region indicated by the oblique lines counterclockwise with a passage of time as shown in Fig. 10B, most of signals inputted in the observation period can be counted. On the contrary, if

the frequency of the carrier signal regenerated on the receiver circuit 1 side is higher than the carrier frequency of the BPSK signal contained in the digital transmission signal, the measuring region indicated by the oblique lines is rotated clockwise with a passage of time. As a result, most of signals inputted in the observation period can be counted. At this time, if the rotation speed of the measuring region is made to coincide with an amount of frequency deviation, a count value obtained by the count operation is maximized. Thus, by

observing whether or not an inputted signal exists in the plural measuring regions, each of them having individual phase rotation speed and phase offset, the amount of the frequency deviation can be detected.

[0081] Fig. 11 is a block diagram showing an example of a circuit structure of the count type fine control AFC circuit using such a basic principle.

[0082] A fine control AFC circuit 45 shown in this Figure comprises an NCO circuit 46 for changing and fixing

an oscillation frequency depending on an inputted frequency difference signal; a phase rotation circuit 47 for rotating the phases of the digitized I baseband signal and Q baseband signal, those signals being outputted from the coarse control AFC block 4, according to a local oscillation signal outputted from this NCO circuit 46; a phase detection circuit 48 for computing arc tangent of the amplitude of the Q baseband signal divided by the amplitude of the I baseband signal, those signals being outputted from the phase rotation circuit 47, so as to generate a phase difference signal; a counter circuit 49 for generating a count value (reference time information) necessary for rotating the measuring region by counting the number of symbols contained in the digital transmission signal; and a region determining circuit 50 which has plural groups of the measuring regions, each of group, for example, has 180 pieces of measuring regions which have different phase offset with predetermined angle step, for example, 1°, determines whether or not a phase difference signal outputted from the phase detection circuit 48 is a phase difference signal in the BPSK modulation period based on a count value outputted from the counter circuit 49, and if the phase difference signal is a phase difference signal in the BPSK modulation period, rotates each measuring region at a different rotation speed depending on each group based on a count value so as to determine in which measuring region of 180 the phase difference signal exists and outputs a pulse signal from an output terminal corresponding to an output terminal in which the phase difference signal exists.

[0083] The fine control AFC circuit 45 comprises a counter block 52 having a number of counter circuits 51 corresponding to frequency resolution × phase resolution, for example, 10 groups if for example, a resolution of 1 kHz is provided and an adjustment region of 10 kHz is provided, and if a width of 180° with an interval of 10° is provided, 18 pieces, totaling 180 counter circuits 51 and thereby counting the number of pulse signals outputted from each output terminal of a region determination circuit 50 for each counter circuit 51; a maximum value determining circuit 53 for comparing count values outputted from each of the counter circuits 51 composing the counter block 52 with each other to determine a counter circuit 51 outputting a count value having the largest value and outputting the counter number of this counter circuit 51; and a conversion ROM circuit 54 in which a number (counter number) of each counter circuit 51 and a value of frequency error are registered as a pair and when a counter number is outputted from the maximum value determination circuit 53, a frequency difference signal indicating a frequency error corresponding to this counter number is generated so as to control the frequency of a local oscillation signal outputted from the NCO circuit 46.

[0084] Thus, the phases of the digitized I baseband signal and Q baseband signal, outputted from the coarse control AFC block 4 are rotated and the I axis

5 side base block signal and Q baseband signal whose phases have been adjusted are supplied to the APC block 6. At the same time, arc tangent of the amplitude of the Q baseband signal whose phase has been adjusted, divided by the amplitude of the I baseband signal whose phases have been adjusted is computed so as to generate a phase difference signal. After that, determining which measuring region, rotated at a different rotation speed depending on group, this phase difference signal exists in. According to this determination result, each counter circuit 51 is counted up depending on the rotation speed and rotation angle. After that, a frequency difference signal indicating a frequency error corresponding to a circuit number of the counter circuit 51 having the largest value of count values of these counter circuits 51 is generated. The frequency of the local oscillation signal is adjusted so as to zero this frequency difference signal and when the value of the frequency difference signal is zeroed, the frequency of the local oscillation signal is fixed.

10 [0085] Using this arrangement, as the same as the fine control AFC circuits 31, 42 shown in Figs. 8, 9, when there is a frequency difference between a carrier signal used in generating a digital transmission signal and a carrier signal regenerated on the receiver circuit 1 side (if there is a detuning in regenerated carrier frequency), it is possible to detect this and zero the frequency deviation of the digitized I baseband signal and Q baseband signal, those signals being outputted from the coarse control AFC block 4.

15 [0086] Although in the fine control AFC circuit 14 shown in Fig. 3, fine control AFC circuit 31 shown in Fig. 8, fine control AFC circuit 32 shown in Fig. 9 and fine control AFC circuit 45 shown in Fig. 11, major parts thereof are composed of ROM, it is permissible to use such a device as high speed DSP (digital signal processor) to carry out the above mentioned processing.

20 [0087] By using those devices, the fine control AFC circuits 14, 31, 32, 45 can be made compact.

25 [0088] According to the above embodiments, the frequency deviation and phase deviation of the digitized I baseband signal and Q baseband signal, outputted from the coarse control AFC block 4 are detected by the fine control AFC block 5 and APC block 6 and these are corrected individually so as to eliminate the frequency deviation and phase deviation of the I baseband signal and Q baseband signal. However it is permissible to detect the frequency deviation and phase deviation of the digitized I baseband signal and Q baseband signal, outputted from the coarse control AFC block 4, by the fine control AFC block 5 and APC block 6 and feed back this detection result to a sweep generator circuit 7 of the coarse control AFC block 4 so as to zero the frequency deviation and phase deviation of the digitized I baseband signal and Q baseband signal, outputted from the coarse control AFC block 4.

30 [0089] Also using this arrangement, as the same as the above described embodiments, upon receiving and

regenerating a digitally modulated signal provided with reference signal period or digitally modulated signal period having few constellation points for regenerating the carrier at a predetermined time interval, the carrier synchronisation is carried out using information about the phase and frequency error obtained periodically and the carrier signal is regenerated stably in a wide capture range so as to regenerate information contained in the digitally modulated signal even when a C/N ratio is low.

[0090] Because the carrier recovery having a wide frequency drawing characteristic can be achieved even at the time of a low C/N ratio, use of a cheap frequency converter is enabled although there are some amounts of frequency drift and phase noise, so that cost of the receiver device can be largely reduced in digital satellite broadcasting.

[0091] Although in the above described embodiments, each of the fine control AFC circuits 14, 31, 32, 45 is actuated in a modulated signal interval having few constellation points so as to generate the regenerative carrier signal, these fine control AFC circuits 14, 31, 32, 45 may be used in an AFC circuit of a device or system other than the above mentioned receiver circuit 1, for example, an AFC circuit of a transmission system for receiving a transmission signal composed of continuous BPSK signals.

[0092] As a result, the inputted modulated signal and carrier signal synchronized in frequency can be regenerated only by actuating these fine control AFC circuits 14, 31, 32, 45.

[0093] Fig. 12 is a block diagram showing still another example of the autocorrelation function type fine control AFC circuit of the fine control AFC circuits for use as the fine control AFC circuit shown in Fig. 2.

[0094] This fine control AFC circuit 55 comprises an NCO circuit 56 for generating a local oscillation signal and changing/fixing the oscillation frequency depending on an inputted frequency difference signal; a phase rotation circuit 57 for rotating the phases of the digitized I baseband signal and Q baseband signal outputted from the coarse control AFC block 4 according to the local oscillation signal outputted from this NCO circuit 56; a phase rotation circuit 58 for providing a frequency offset to the rotated I baseband signal and Q baseband signal; an NCO circuit 59 for providing this phase rotation circuit 58 with an local oscillation signal based on the offset frequency data; a phase detection circuit 60 for computing arc tangent of the amplitude of the Q baseband signal divided by the amplitude of the I baseband signal outputted from the phase rotation circuit 58 so as to generate a phase difference signal; an autocorrelation computing circuit 61 for obtaining an autocorrelation coefficient of a phase difference signal outputted from this phase detection circuit 60 so as to generate a correlation coefficient signal; an integration circuit 62 for integrating some frames of the autocorrelation coefficient signals outputted from this self-correlation computing circuit 61 using time series addition method such

as average integration method by inter-frame addition so as to reduce the influence of noise; a counter circuit (or period detection circuit for measuring the period of periodic waveform appearing in the autocorrelation coefficient signal) 63 for counting the number of correlation peaks in the autocorrelation coefficient signal outputted from this integration circuit 62; a frequency data generation ROM 64 for generating frequency difference signal (frequency data) corresponding to this count

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335 340 345 350 355 360 365 370 375 380 385 390 395 400 405 410 415 420 425 430 435 440 445 450 455 460 465 470 475 480 485 490 495 500 505 510 515 520 525 530 535 540 545 550 555 560 565 570 575 580 585 590 595 600 605 610 615 620 625 630 635 640 645 650 655 660 665 670 675 680 685 690 695 700 705 710 715 720 725 730 735 740 745 750 755 760 765 770 775 780 785 790 795 800 805 810 815 820 825 830 835 840 845 850 855 860 865 870 875 880 885 890 895 900 905 910 915 920 925 930 935 940 945 950 955 960 965 970 975 980 985 990 995 1000 1005 1010 1015 1020 1025 1030 1035 1040 1045 1050 1055 1060 1065 1070 1075 1080 1085 1090 1095 1100 1105 1110 1115 1120 1125 1130 1135 1140 1145 1150 1155 1160 1165 1170 1175 1180 1185 1190 1195 1200 1205 1210 1215 1220 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3225 3230 3235 3240 3245 3250 3255 3260 3265 3270 3275 3280 3285 3290 3295 3300 3305 3310 3315 3320 3325 3330 3335 3340 3345 3350 3355 3360 3365 3370 3375 3380 3385 3390 3395 3400 3405 3410 3415 3420 3425 3430 3435 3440 3445 3450 3455 3460 3465 3470 3475 3480 3485 3490 3495 3500 3505 3510 3515 3520 3525 3530 3535 3540 3545 3550 3555 3560 3565 3570 3575 3580 3585 3590 3595 3600 3605 3610 3615 3620 3625 3630 3635 3640 3645 3650 3655 3660 3665 3670 3675 3680 3685 3690 3695 3700 3705 3710 3715 3720 3725 3730 3735 3740 3745 3750 3755 3760 3765 3770 3775 3780 3785 3790 3795 3800 3805 3810 3815 3820 3825 3830 3835 3840 3845 3850 3855 3860 3865 3870 3875 3880 3885 3890 3895 3900 3905 3910 3915 3920 3925 3930 3935 3940 3945 3950 3955 3960 3965 3970 3975 3980 3985 3990 3995 4000 4005 4010 4015 4020 4025 4030 4035 4040 4045 4050 4055 4060 4065 4070 4075 4080 4085 4090 4095 4100 4105 4110 4115 4120 4125 4130 4135 4140 4145 4150 4155 4160 4165 4170 4175 4180 4185 4190 4195 4200 4205 4210 4215 4220 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9225 9230 9235 9240 9245 9250 9255 9260 9265 9270 9275 9280 9285 9290 9295 9300 9305 9310 9315 9320 9325 9330 9335 9340 9345 9350 9355 9360 9365 9370 9375 9380 9385 9390 9395 9400 9405 9410 9415 9420 9425 9430 9435 9440 9445 9450 9455 9460 9465 9470 9475 9480 9485 9490 9495 9500 9505 9510 9515 9520 9525 9530 9535 9540 9545 9550 9555 9560 9565 9570 9575 9580 9585 9590 9595 9600 9605 9610 9615 9620 9625 9630 9635 9640 9645 9650 9655 9660 9665 9670 9675 9680 9685 9690 9695 9700 9705 9710 9715 9720 9725 9730 9735 9740 9745 9750 9755 9760 9765 9770 9775 9780 9785 9790 9795 9800 9805 9810 9815 9820 9825 9830 9835 9840 9845 9850 9855 9860 9865 9870 9875 9880 9885 9890 9895 9900 9905 9910 9915 9920 9925 9930 9935 9940 9945 9950 9955 9960 9965 9970 9975 9980 9985 9990 9995 9999

Industrial Applicability

[0097] According to each AFC circuit of the present invention, as described above, when the reference signal period or the modulated signal period having few constellation points which can be used for carrier recovery, contained in a input signal, is short or when noise is mixed in the input signal, it is possible to regenerate a carrier signal synchronized with the input signal while suppressing occurrence of false lock.

[0098] Further, according to each carrier recovery circuit of the present invention, upon transmitting a modulated signal having different numbers of constellation points by time division method and receiving the signal for regeneration, it is possible to carry out carrier synchronization using information about the phase and frequency error obtained periodically and reproduce the carrier signal stably in a wide capture range, even when the C/N ratio is low.

[0099] Further, according to each receiver device of the present invention, upon receiving and reproducing a digitally modulated signal provided with the reference signal period or with digitally modulated signal period having few constellation points to be useful for carrier recovery at a predetermined time interval, it is possible to carry out carrier synchronization using information about the phase and frequency error obtained periodically and reproduce the carrier signal stably in a wide capture range so as to reproduce information contained in digitally modulated signal, even when the C/N ratio is low.

Claims

1. An AFC circuit for detecting a frequency difference between two inputted signals and zeroing said frequency difference between the inputted signals according to the detection result, the AFC circuit comprising:

a frequency difference detecting portion for detecting a phase difference between the inputted signals and generating a frequency correction signal according to the phase difference or a time differential value of the phase difference; and

a frequency difference correcting portion for rotating the phase of the inputted signal according to the frequency correction signal outputted from the frequency difference detecting portion so as to zero the frequency difference between the inputted signals.

2. An AFC circuit for detecting a frequency difference between two inputted signals and zeroing said frequency difference between the inputted signals according to the detection result, the AFC circuit comprising:

a correlation computing portion for detecting a phase difference between the inputted signals and computing an autocorrelation coefficient of the phase difference; and

a frequency difference correcting portion for counting a number of peaks in a waveform of the autocorrelation coefficient obtained by the correlation computing portion and rotating phase of the inputted signals according to the count result so as to zero the frequency difference between the inputted signals.

3. An AFC circuit for detecting a frequency difference between two inputted signals and zeroing said frequency difference between the inputted signals according to the detection result, the AFC circuit comprising:

a correlation computing portion for detecting a phase difference between the inputted signals and computing an autocorrelation coefficient of a waveform varying in time of the phase difference; and

a frequency difference correcting portion for obtaining an average period of a periodic waveform appearing in a waveform of the autocorrelation coefficient obtained by the correlation computing portion and rotating a phase between the inputted signals according to the average period so as to zero the frequency difference of the inputted signals.

4. An AFC circuit for detecting a frequency difference between two inputted signals and zeroing said frequency difference between the inputted signals according to the detection result, the AFC circuit comprising:

a region determining portion for detecting a phase difference between the inputted signals and determining which region each signal point is included in according to the phase difference; and

a frequency difference correcting portion for counting a determination result of the region determining portion for each phase and for each determining region rotated at a rotation speed corresponding to a set frequency, and rotating phase of the inputted signals according to the count result so as to zero the frequency difference between the inputted signals.

5. A carrier recovery circuit for regenerating a carrier signal from an I baseband signal and a Q baseband signal obtained by quadrature-demodulating a reception signal, the circuit comprising:

a frequency difference detecting portion for

- detecting a phase difference between the regenerated carrier signal and the reception signal from the I axis side signal and the Q axis side signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal; and generating a frequency correction signal according to the phase difference or a differential value of the phase difference; and
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- a frequency difference correcting portion for controlling a frequency of the regeneration carrier signal according to the frequency correction signal outputted from the frequency difference detecting portion so as to zero a frequency difference between the reception signal and the regeneration carrier signal.
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6. A carrier recovery circuit for regenerating a carrier signal from an I baseband signal and a Q baseband signal obtained by quadrature-demodulating a reception signal, the circuit comprising:
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- a correlation computing portion for detecting a phase difference between the regenerated carrier signal and the reception signal from the I axis side signal and the Q axis side signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal so as to compute autocorrelation coefficients of the phase difference; and
- 25
- a frequency difference correcting portion for counting a peak in the waveform of the autocorrelation coefficient waveform obtained by the correlation computing portion and controlling a frequency of the regenerated carrier signal according to the count result so as to zero the frequency difference between the reception signal and the regenerated carrier signal.
- 30
7. A carrier recovery circuit for regenerating a carrier signal from an I baseband signal and a Q baseband signal obtained by quadrature-demodulating a reception signal, the circuit comprising:
- 35
- a correlation computing portion for detecting a phase difference between the regenerated carrier signal and the reception signal from the I baseband signal and the Q baseband signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal so as to compute autocorrelation coefficients of the phase difference; and
- 40
- a frequency difference correcting portion for obtaining an average period of a periodic waveform appearing in a waveform of the autocorrelation coefficient obtained by the correlation computing portion, and controlling a frequency of the regenerated carrier signal based on the
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5. 8. A carrier recovery circuit for regenerating a carrier signal from an I baseband signal and a Q baseband signal obtained by quadrature-demodulating a reception signal, the circuit comprising:
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- average period so as to zero the frequency difference between the reception signal and the regenerated carrier signal.
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- a region determining portion for detecting a phase difference between the regenerated carrier signal and the reception signal from the I axis side signal and the Q axis side signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal, and determining which region of a phase plane each signal point is included in based on the phase difference; and
- 60
- a frequency difference/phase difference correcting portion for counting a determination result of the region determining portion for each phase and for each determination region rotated at a rotation speed corresponding to a set frequency, and controlling frequency and phase of the regenerated carrier signal based on the count result so as to zero a frequency difference and the phase difference between the reception signal and the regenerated carrier signal.
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9. A receiver device for regenerating a carrier signal based on the I baseband signal and the Q baseband signal obtained by quadrature-demodulating a reception signal, and decoding the I baseband signal and the Q baseband signal so as to regenerate information, said receiver device further
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- receiving a digitally modulated signal provided with a reference signal period or a digitally modulated signal period having few constellation points to be used for carrier recovery at a predetermined time interval; and
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- establishing carrier synchronization using information about phase error and frequency error obtained in the reference signal period or in the digitally modulated signal period having few constellation points.
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10. A receiver device for regenerating a carrier signal based on the I baseband signal and the Q baseband signal obtained by quadrature-demodulating a reception signal, and decoding the I baseband signal and the Q baseband signal so as to regenerate information, said receiver device further
- 85
- receiving a digitally modulated signal provided with a reference signal period or a digitally modulated signal period having few constella-

- tion points to be used for carrier recovery at a predetermined time interval; and
detecting a difference between a regeneration carrier frequency and a carrier frequency of the reception signal obtained in a reference signal period or in a digitally modulated signal period having few constellation points so as to achieve at least one of AFC function or false lock preventing function based on the detection result.
11. A receiver device according to claim 10 wherein a regeneration carrier frequency is controlled according to detuning frequency information obtained by time differential value or a primary inclination of a change of a phase obtained by observing a phase variation in a reference signal period of a reception signal or in a modulated signal period having few constellation points, under a state of frequency asynchronization.
12. A receiver device according to claim 10 wherein a detuning frequency is estimated based on periodicity of an autocorrelation coefficient waveform in a phase variation curve obtained by observing a phase variation in a reference signal period of a reception signal or in a modulated signal period having few constellation points and then a regeneration carrier frequency is controlled based on detuning frequency information obtained by the estimation operation, under a state of frequency asynchronization.
13. A receiver device according to claim 12 wherein the regeneration carrier frequency is set at a low frequency preliminarily so as to provide a frequency of a waveform or a number of correlation peaks appearing in the autocorrelation coefficient waveform relative to a desired frequency with an offset, thereby making it possible to estimate a detuning frequency lower than the desired frequency.
14. A receiver device according to claim 12 wherein whether or not carrier synchronization is established is detected based on a statistical characteristic of phase points of a signal in a modulation period having few constellation points and oscillation frequency sweep of a local oscillator for use for frequency conversion is stopped based on the detection result.
15. A receiver device for regenerating a carrier signal based on the I baseband signal and the Q baseband signal obtained by quadrature-demodulating a reception signal, and decoding the I baseband signal and the Q baseband signal so as to regenerate information, said receiver device further including a carrier recovery circuit comprising:
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- a receiving portion for receiving a digitally modulated signal provided with a reference signal period or with a digital modulation period having few constellation points to be used for carrier recovery at a predetermined time interval so as to obtain the reception signal;
a region determining portion for detecting a phase difference between the regenerated carrier signal and the reception signal from the I axis side signal and the Q axis side signal obtained by quadrature-demodulating the reception signal by the regenerated carrier signal, and determining which region of a phase plane each signal point is included in based on the phase difference; and
a frequency difference/phase difference correcting portion for counting a determination result of the region determining portion for each phase and for each determination region rotated at a rotation speed corresponding to a set frequency, and controlling frequency and phase of the regenerated carrier signal based on the count result so as to zero a frequency difference and the phase difference between the reception signal and the regenerated carrier signal,
whereby at least one of AFC function or false lock preventing function being achieved.

30 Amended claims under Art. 19.1 PCT

1. (Cancel)

2. An AFC circuit for detecting a frequency difference between two inputted signals and zeroing said frequency difference between the inputted signals according to the detection result, the AFC circuit comprising:

a correlation computing portion for detecting a phase difference between the inputted signals and computing an autocorrelation coefficient of the phase difference; and
a frequency difference correcting portion for counting a number of peaks in a waveform of the autocorrelation coefficient obtained by the with a reference signal period or a digitally modulated signal period having few constellation points to be used for carrier recovery at a predetermined time interval; and
detecting a difference between a regeneration carrier frequency and a carrier frequency of the reception signal obtained in a reference signal period or in a digitally modulated signal period having few constellation points so as to achieve at least one of AFC function or false lock preventing function based on the detection result.

11. A receiver device according to claim 10 wherein a regeneration carrier frequency is controlled according to detuning frequency information obtained by time differential value or a primary inclination of a change of a phase obtained by observing a phase variation in a reference signal period of a reception signal or in a modulation signal period having few constellation points, under a state of frequency asynchronization. 5

12. (Amended) A receiver device according to claim 10 wherein an average period of a periodical waveform appearing in an autocorrelation coefficient waveform in a phase variation curve obtained by observing a phase variation in a reference signal period of a reception signal or in a modulation signal period having few constellation points is obtained and then, based on the obtained average period, a detuning frequency is estimated, and then a regeneration carrier frequency is controlled based on detuning frequency information obtained by the estimation operation, under a state of frequency asynchronization. 10 15 20

13. (Amended) A receiver device according to claim 12 wherein the regeneration carrier frequency is set at a low frequency preliminarily so as to provide an average period of a periodical waveform or a number of correlation peaks appearing in the autocorrelation coefficient waveform relative to a desired frequency with an offset, thereby making it possible to estimate a detuning frequency lower than the desired frequency. 25 30

14. A receiver device according to claim 12 wherein whether or not carrier synchronization is established is detected based on a statistical characteristic of phase points of a signal in a modulation period having few constellation points and oscillation frequency sweep of a local oscillator for use for frequency conversion is stopped based on the detection result. 35 40

15. A receiver device for regenerating a carrier signal based on the I baseband signal and the Q baseband signal obtained by quadrature-demodulating a reception signal, and decoding the I baseband signal and the Q baseband signal so as to regenerate information, said receiver device further including a carrier recovery circuit comprising: 45 50

a receiving portion for receiving a digitally

FIG.1

- SIGNAL A: SYNC (UW)
- SIGNAL B: BPSK SIGNAL PERIOD
(FOR CARRIER FREQUENCY SYNCHRONIZATION)
- SIGNAL C: BPSK SIGNAL PERIOD
(FOR CARRIER PHASE SYNCHRONIZATION)
- SIGNAL D: SIGNAL PERIOD HAVING MANY CONSTELLATION POINTS

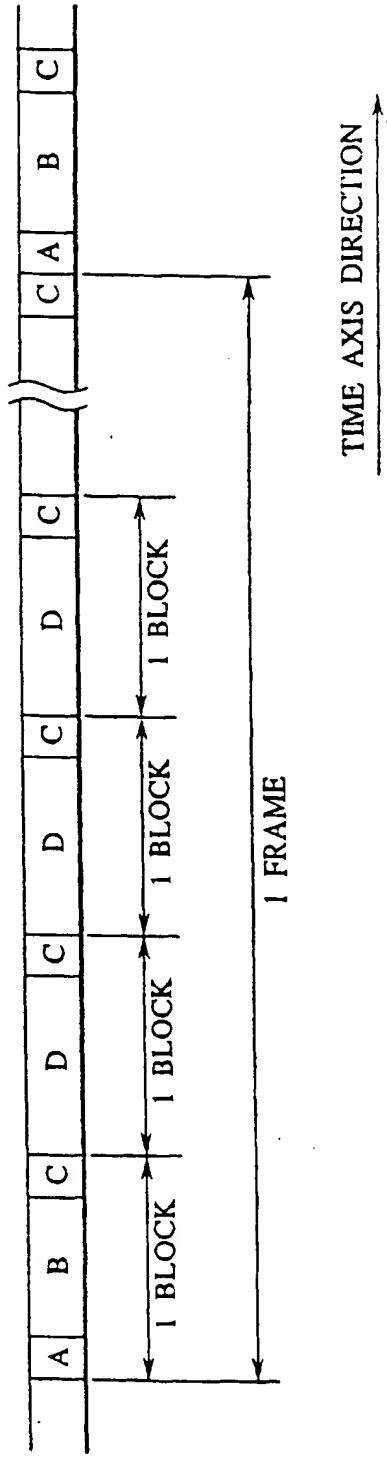


FIG.2

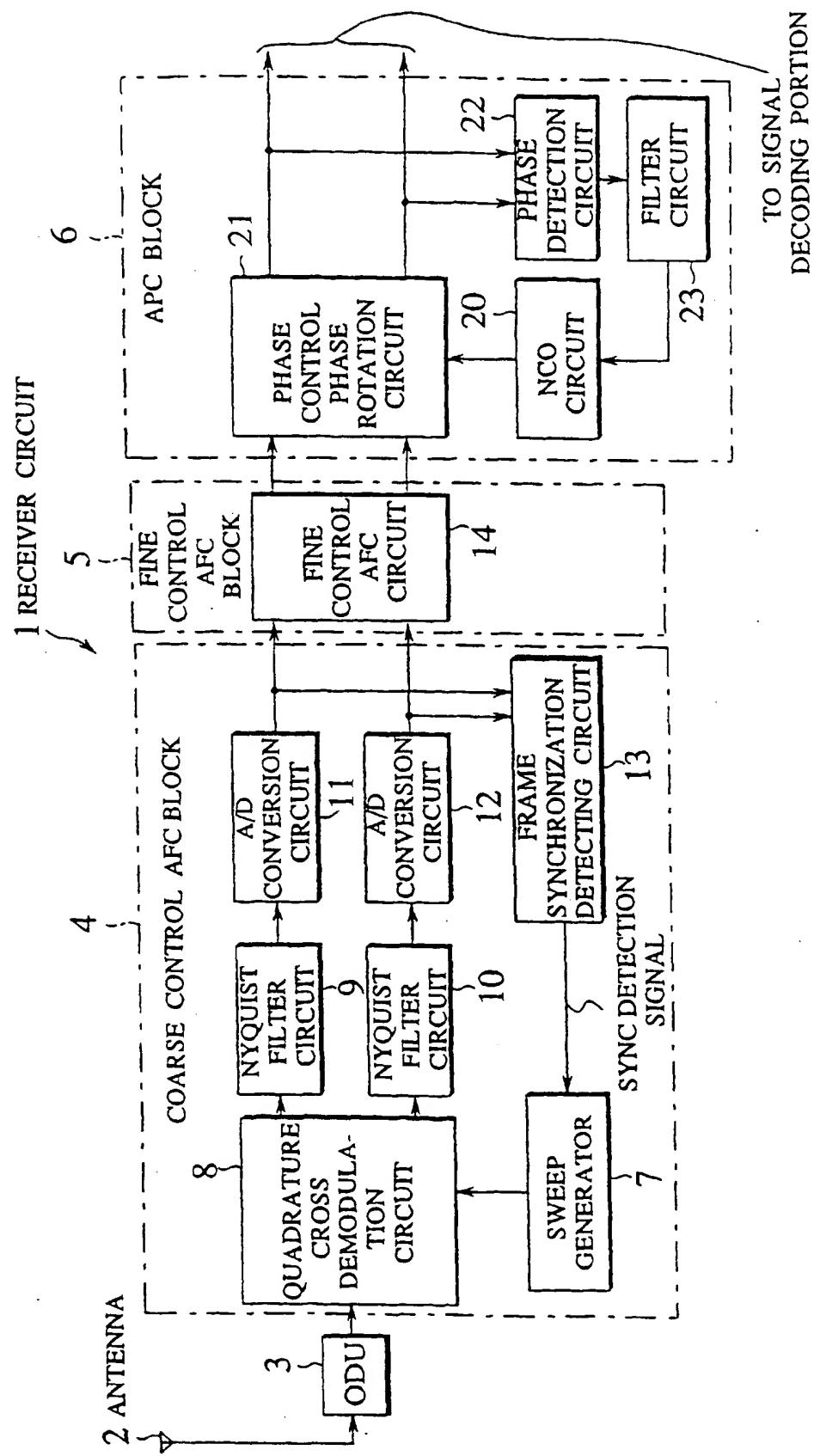


FIG.3

14

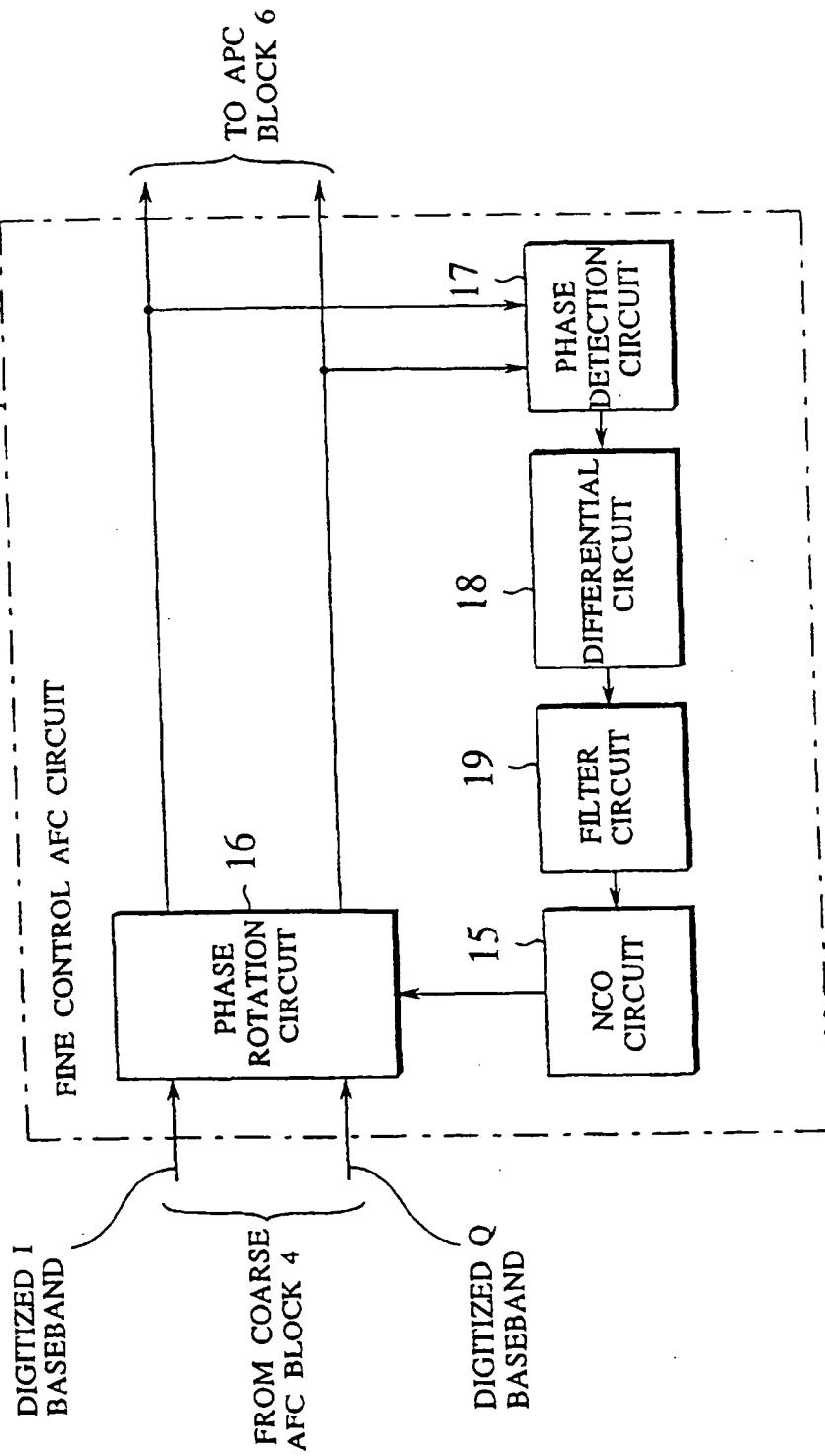


FIG.4

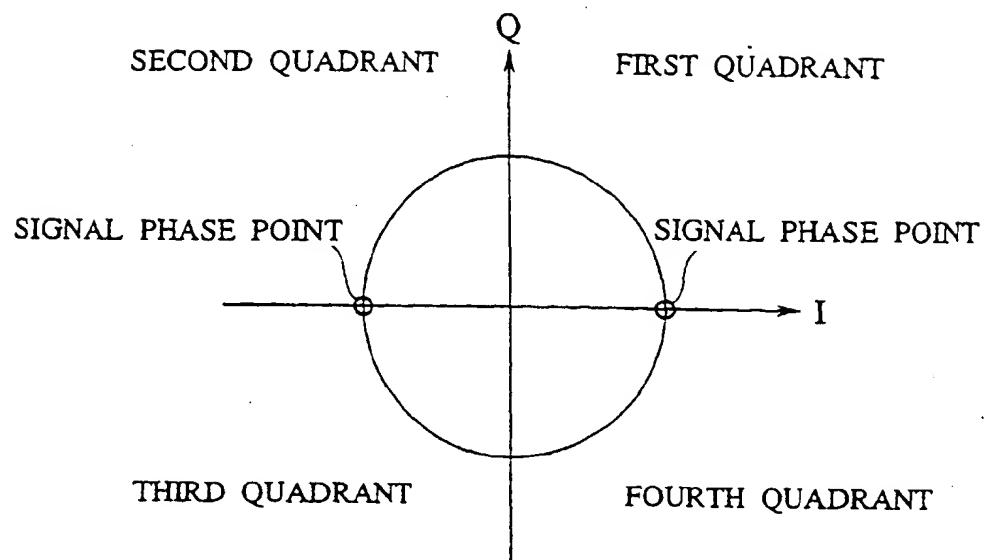


FIG.5

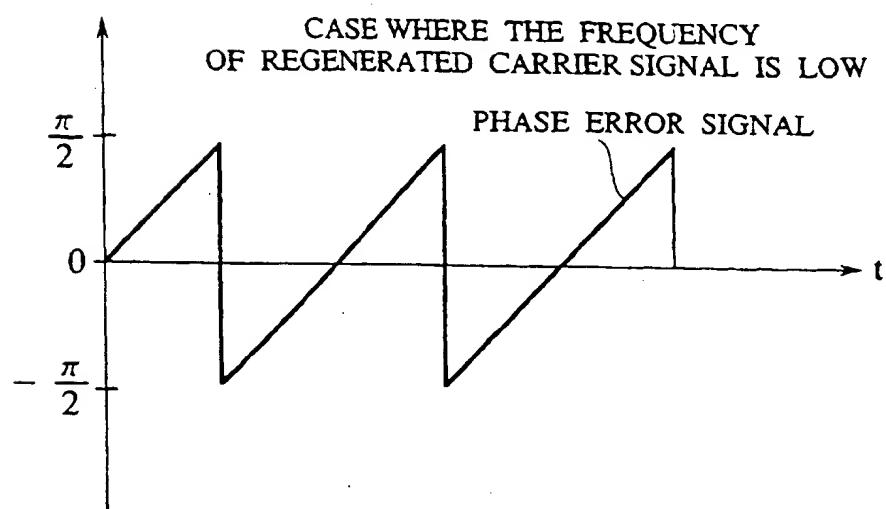


FIG.6

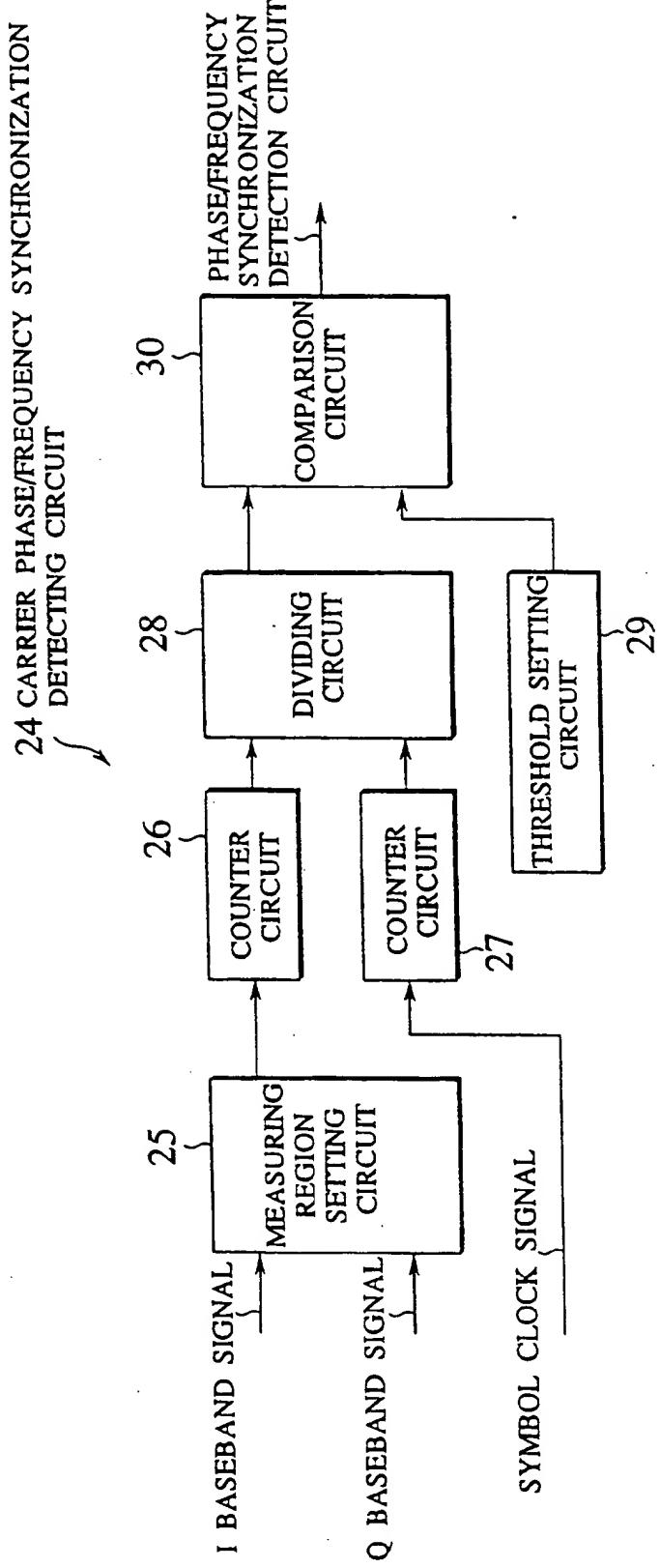


FIG.7

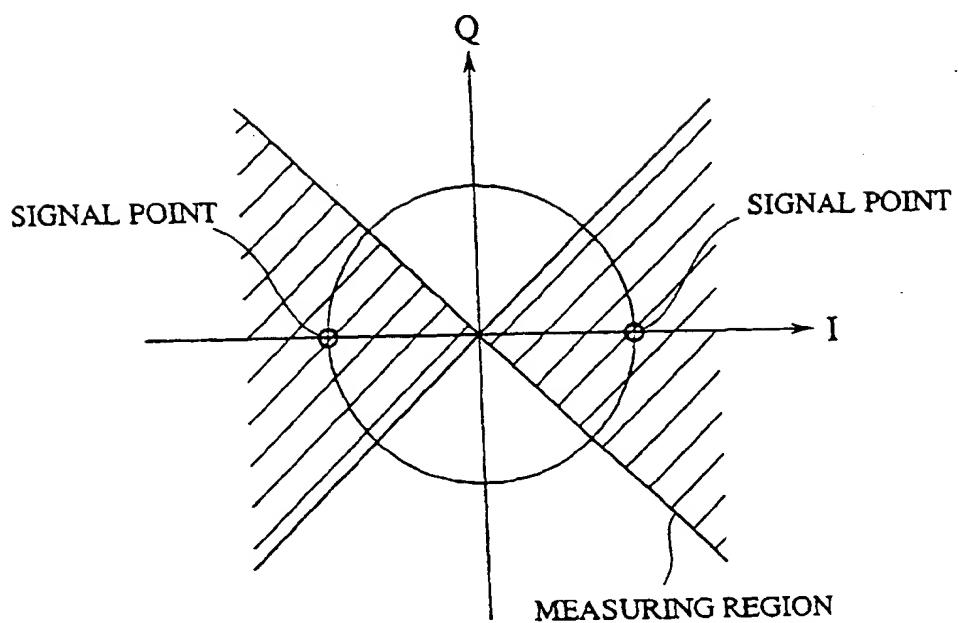


FIG.8

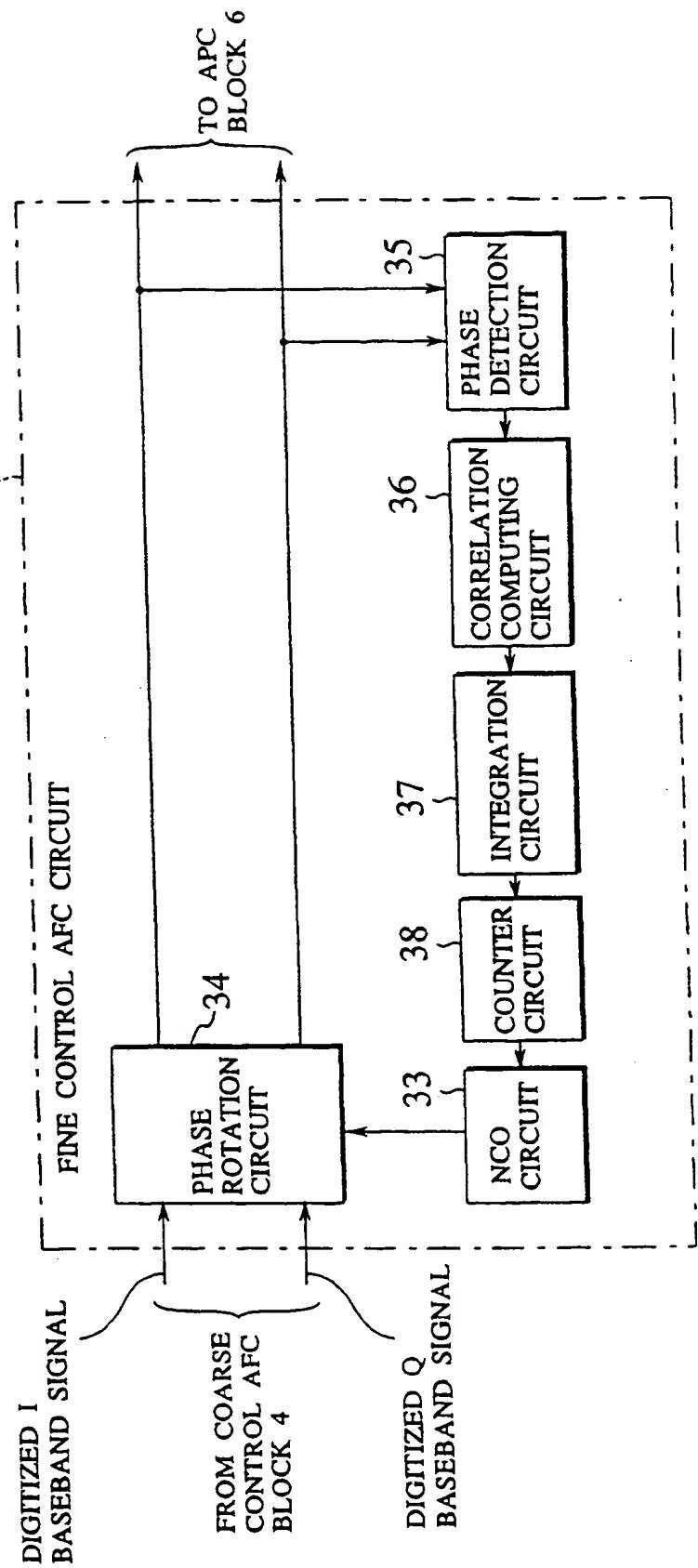


FIG.9

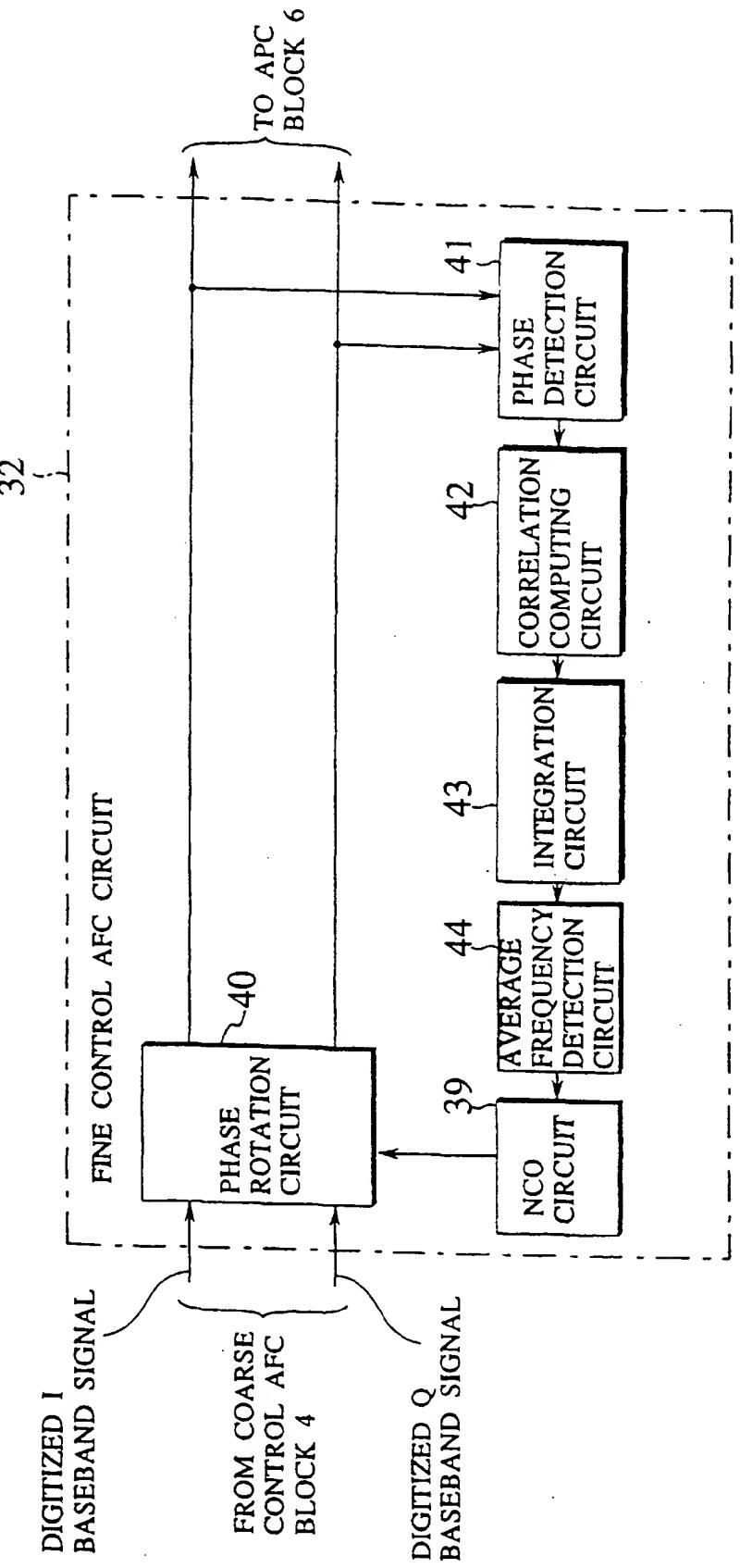


FIG.10A

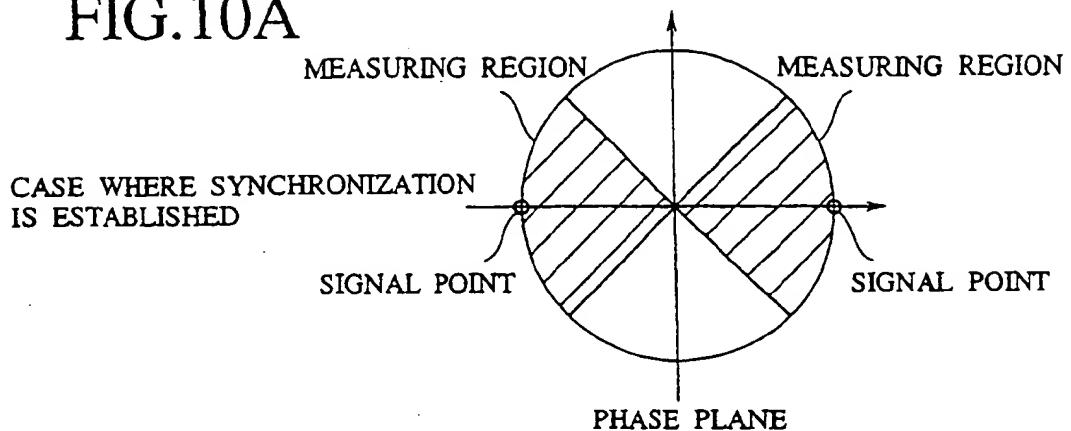


FIG.10B

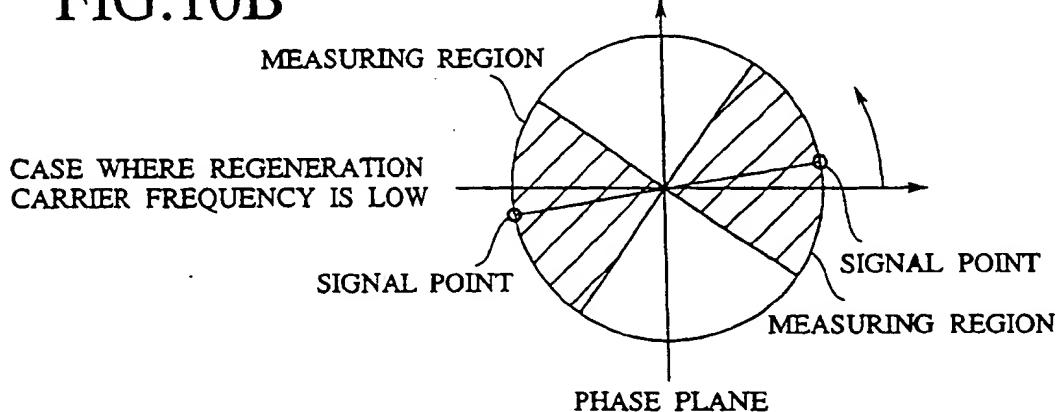


FIG.10C

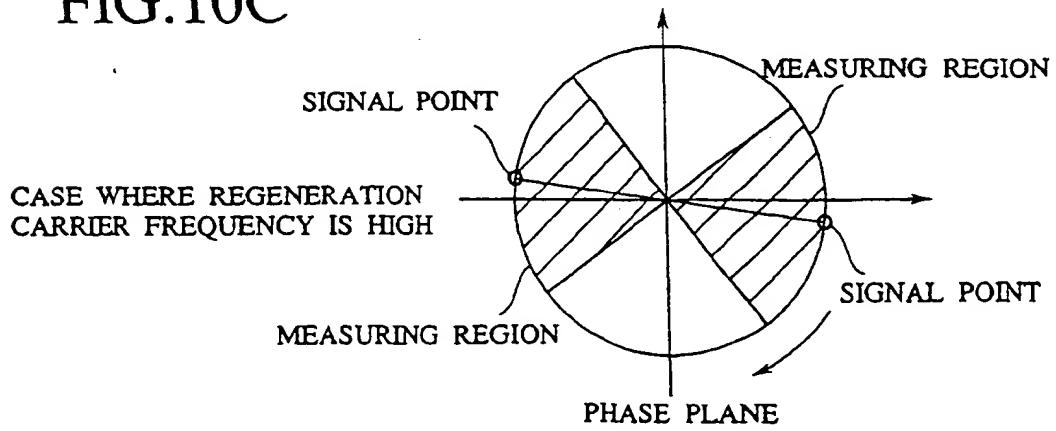


FIG. 11

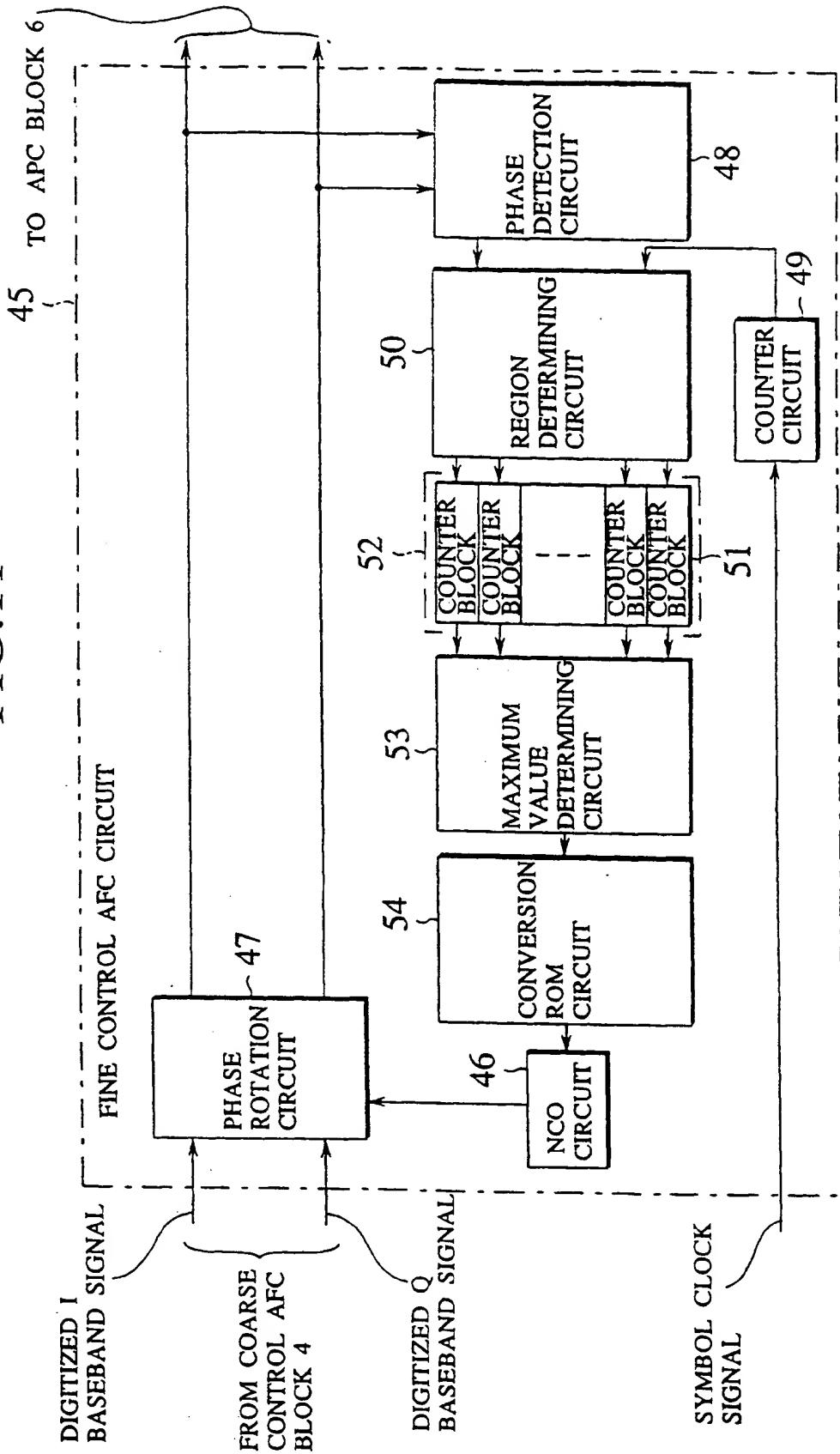
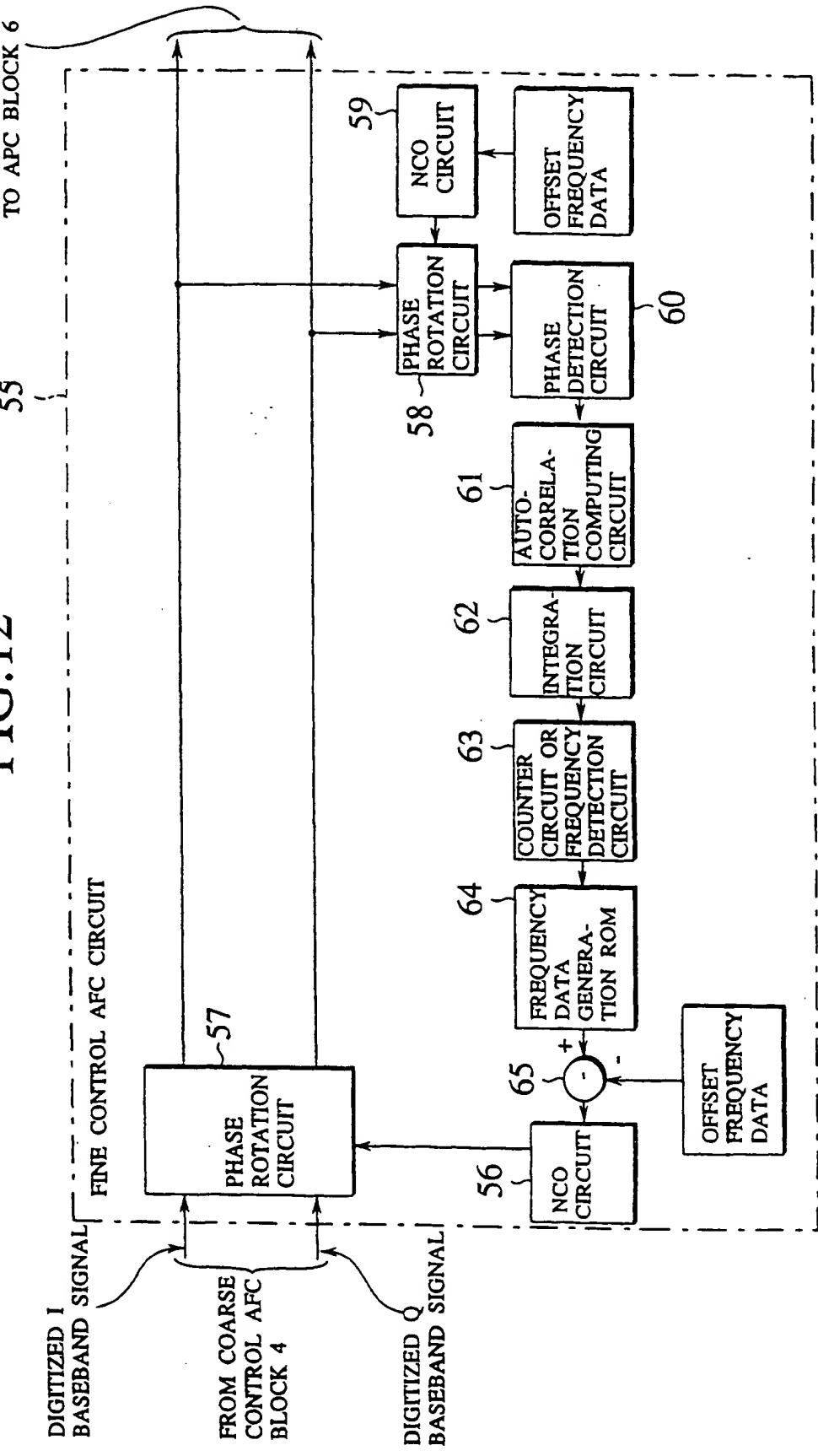


FIG.12



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/04206

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl' H04L27/22, H04N5/455		
According to International Patent Classification (IPC) or to both national classification and IPC.		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) Int.Cl' H04L27/00-38, H04N5/455		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1940-1998 Kokai Jitsuyo Shinan Koho 1971-1998		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP, 5-211535, A (Fujitsu Ltd.), 20 August, 1993 (20. 08. 93), Page 3, column 4, line 30 to page 4, column 5, lines 6, 25 to 39 ; Figs. 1, 3 & US, 5373247, A	1, 5 11
X Y	JP, 8-307408, A (Motorola, Inc.), 22 November, 1996 (22. 11. 96), Figs. 1, 2 & GB, 2300093, A	2, 3, 6, 7 12
X	JP, 6-276244, A (Matsushita Communication Industrial Co., Ltd.), 30 September, 1994 (30. 09. 94), Figs. 1, 3 (Family: none)	4, 8
X Y	JP, 63-234759, A (Hitachi, Ltd.), 30 September, 1988 (30. 09. 88), Fig. 1 & US, 4856027, A	9, 10 11, 12
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
<p>* Special categories of cited documents:</p> <p>'A' document defining the general state of the art which is not considered to be of particular relevance</p> <p>'E' earlier document but published on or after the international filing date</p> <p>'L' document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>'O' document referring to an oral disclosure, use, exhibition or other means</p> <p>'P' document published prior to the international filing date but later than the priority date claimed</p> <p>'T' later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>'X' document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>'Y' document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>'&' document member of the same patent family</p>		
Date of the actual completion of the international search 2 December, 1998 (02. 12. 98)	Date of mailing of the international search report 15 December, 1998 (15. 12. 98)	
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer	
Facsimile No.	Telephone No.	

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP98/04206

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 8-335959, A (Matsushita Electric Industrial Co., Ltd.), 17 December, 1996 (17. 12. 96), Page 23, column 44, line 38 to page 26, column 49, line 21 ; page 29, column 56, line 42 to page 30, column 57, line 10 ; Figs. 18 to 20, 31 & EP, 689324, A2	1-15

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